National Spatial Data Infrastructure

NSDI FRAMEWORK TRANSPORTATION IDENTIFICATION STANDARD -- *Public Review Draft*

Ground Transportation Subcommittee
Federal Geographic Data Committee

December, 2000

Federal Geographic Data Committee

Established by Office of Management and Budget Circular A-16, the Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geographic data.

The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior, Justice, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; the National Science Foundation; and the Tennessee Valley Authority. Additional Federal agencies and non-Federal agencies participate on FGDC subcommittees and working groups. The Department of the Interior chairs the committee.

FGDC subcommittees work on issues related to data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort. Working groups are established for issues that transcend data categories.

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The following is the recommended bibliographic citation for this publication:
Federal Geographic Data Committee (Ground Transportation Subcommittee): NSDI Framework Transportation Identification Standard (Working Draft). Washington, D.C., 2000.

CONTENTS

Page

1   1   **Introduction**

2   1.1   Preface

3   1.1.1   Background

4   Many users of geospatial data within both the transportation and GIS communities have

5   questions about the relationships among transportation features such as roads, their

6   representation as geo-spatial objects in geographic information systems (GIS), and their

7   representation in analytical networks. Much of this confusion results from the inconsistent

8   use of terminology to describe transportation features and their representations. It is also

9   perpetuated by current versions of GIS software, which fail to adequately address the

10   differences between lines used for cartographic displays and those used for network

11   analysis.

12   1.1.2   Need for Standards

13   One consequence of this confusion has been an inability to promulgate national standards

14   for transportation spatial features to facilitate data sharing under the **National Spatial**

15   **Data Infrastructure (NSDI)** initiative. A fundamental requirement of spatial data sharing

16   is that both the supplier and the recipient of the data understand what the data represents

17   in terms of real-world features. This is relatively straightforward for features having well

18   defined boundaries such a building or airport. However, many transportation features are

19   characterized by extensive linear networks, with no universally agreed upon standard for

20   partitioning these networks into unique "segments." Each developer of a transportation

21   network spatial database partitions the network to meet his or her specific application

22   needs.

23   1.1.3   FGDC Action

24   The **Federal Geographic Data Committee (FGDC)** was established by the Office of

25   Management and Budget (OMB) under Circular A-16 to promote the coordinated

26   development, use, sharing, and dissemination of geographic data. The committee, which

27   is composed of representatives from 17 departments and independent agencies, oversees

28   and provides policy guidance for agency efforts to coordinate geographic data activities.

29   The FGDC created the **Ground Transportation Subcommittee** in January 1992 to

30   address data issues involving transportation features and networks. The objectives of the

31   Subcommittee are to:

32   --   promote standards of accuracy and currency in ground transportation data which is

33   financed in whole or in part by Federal funds;

34   --   exchange information on technological improvements for collecting ground

35   transportation data;

36   --   encourage the Federal and non-Federal community to identify and adopt standards

37   and specifications for ground transportation data; and

38   --   promote the sharing of ground transportation data among Federal and non-Federal

39   organizations.

40   1.1.4   NSDI Framework Data

41   Transportation is one of the seven Framework layers identified in the National Spatial

42   Data Infrastructure. NSDI framework data represents the "best" available geo-spatial data

43   for an area. The data is collected or compiled to a known level of spatial accuracy and

44   currency, documented in accordance with established metadata standards, and made

45   available for dissemination at little or no cost and free of restrictions on use. Framework

46   data is not necessarily uniform from one area to another; the quality of the data for a given

47   area depends on the requirements of the participating data developers. The NSDI does

48   not specify threshold standards for spatial accuracy, attribution, completeness of coverage,

49   or currency for any of its framework themes. The resulting framework will be a

50   "patchwork quilt" consisting of high quality geo-spatial data for some geographic areas,

51   with lower quality or even missing data for other areas. As more data developers upgrade

52   their geo-spatial data and participate in the NSDI, the overall quality of the data

53   comprising the NSDI Framework and the completeness of nationwide coverage will

54   improve. For further information see the FGDC publication "NSDI Framework

55   Introduction and Guide," http://www.fgdc.gov/framework/frameworkintroguide/ .

56   1.1.5   The Transportation Framework Data Layer

57   The importance of geo-spatial data depicting transportation features – especially road

58   networks – extends well beyond their cartographic value. Road networks provide the

59   basis for several indirect location referencing systems, including street addresses and

60   various linear referencing methods commonly used to locate features like bridges, signs,

61   pavement conditions, and traffic incidents. Geo-spatial transportation segments can be

62   connected to form topological networks, which can be used to more accurately measure

63   over-the-road travel distances between geographic locations. Furthermore, when

64   combined with the variety of network analysis tools that are available, topological

65   networks can be used to find the shortest paths between two or more locations, to

66   determine the most efficient route to cover all transportation segments (e.g., for planning

67   of snow removal), or to estimate traffic volumes by assigning origin-to-destination flows

68   to network segments.

69   Integration of the "best available" transportation databases into a national framework layer

70   must provide for nationwide connectivity in order to support the network applications

71   described above. This means that there can be no "gaps" (geographic areas where

72   transportation data is totally absent). Further, the transportation data for each particular

73   geographic area must be produced so that it can be connected topologically to

74   transportation data for adjacent areas.

75   1.1.6   Federal, State and Local Transportation Data Resources

76   A nationwide NSDI framework road layer *could* be constructed from the national level

77   databases developed by federal agencies: **Bureau of the Census** TIGER/Line files, **U.S.**

78   **Geological Survey** Digital Line Graph (USGS/DLG) files, and the National Highway

79   Planning Network (NHPN) developed by the **Federal Highway Administration**

80   (FHWA). These databases serve most federal needs and many general public

81   requirements for national level road data at the 1:100,000 scale, and provide network

82   connectivity in those areas where more accurate transportation data does not exist.

83   However, such a database would not offer the currency, completeness, and accuracy

84   required by many other users.

85   Over half of the state Departments of Transportation (DOTs) have developed road

86   databases at a scale of 1:24,000 or better. These databases are almost certainly of

87   superior accuracy, completeness and currency than the national databases, and *could* take

88   the place of federal road data as the framework database for their respective areas,

89   providing they meet other NSDI framework requirements (e.g., metadata documentation,

90   no restrictions on use). Road data which is even more accurate and current exists for

91   many smaller geographic units; e.g. counties or metropolitan areas. These databases *could*

92   be utilized instead of either the federal or state transportation data as the framework

93   database for their specific areas.

94   1.1.7   The Challenge

95   Creation of the NSDI framework transportation layer will require the participation of a

96   large number of federal, state, and local transportation agencies, and their contribution of

97   transportation databases developed for specific geographic areas and applications. The

98   databases will be – or have been – developed at different scales, with different levels of

99   positional accuracy, detail and completeness of coverage, and currency. These databases

100   will have to be "stitched together" in order to provide the network connectivity required

101   for many transportation applications. When new databases are added to the framework,

102   or when specific attributes are updated or enhanced, users of framework data will need to

103   be able to incorporate this new information into their applications in ways that are cost-

104   effective.

105   The process of transferring information (including more accurate coordinates) from one

106   geo-spatial database to another is known as "conflation." Successful conflation requires

107   that the features in one geo-spatial database be matched to their counterparts in the other

108   database. Once this match is achieved, geometric and/or attribute data can be exchanged

109   from either of the two databases to the other. For example, coordinate data depicting the

110   alignment of a transportation segment can be transferred from a transportation database

111   digitized from 1:12,000 scale digital orthophotoquads (DOQs) to a database that had

112   originally been digitized from 1:24,000 scale USGS topographic maps.

113   Typically the process of conflation uses a combination of coordinate matching and name

114   matching. Depending on the similarity of the two databases, the percentage of

115   successfully matched features can vary from over 90 percent to well under 50 percent.

116   This range of variability is unacceptable for successful implementation of the NSDI

117   framework, which will require ongoing additions of new framework databases and

118   transactional updates to attributes in existing framework databases.

119   A more promising conflation method starts with the assignment of a stable and unique

120   identifier to each geo-spatial feature. This identifier can then be used to match features

121   across databases without having to rely on coordinate accuracy or the use of standard

122   names. Unique feature identifiers work best when instances of features are well defined

123   and spatially distinct.

124   The identification of a discreet feature instance is not always obvious for linear features

125   such as roads and surface waters. Roads are segmented in an almost infinite number of

126   ways, depending on the application needs of the database developer. Roads may be

127   segmented at intersections for path building, or at changes in one or more attributes for

128   use in facility management. Also, a transportation segment may terminate at a state,

129   county, or municipal border, or other jurisdictional boundary.

130   Within the same geographical area multiple entities may create, update, and/or use

131   different transportation databases. For example, a state DOT may create a transportation

132   database that includes only state highways, and may segment its roads wherever one

133   highway intersects another. A local transportation planning agency might create a

134   database for the same area that includes all local roads; this agency could segment the

135   state highways wherever they intersect any road. Finally, an E-911 agency could create

136   yet a third transportation database for the area, segmenting all roads at each private

137   driveway.

138   Most geographic information system (GIS) software packages currently do not enable the

139   user to distinguish between an instance of a linear geo-spatial feature and how that feature

140   is represented in a topological network. Each of the transportation databases mentioned

141   above represents the same physical transportation network but divides it into different –

142   often overlapping – segments in order to establish topological connections needed for the

143   respective applications. Each segment becomes a distinct record in the geo-spatial

144   database unique to that application. Finding a set of common transportation segments that

145   carry topology and are useful in all existing and potential applications is impossible in most

146   geographic areas.

147   The concept of a permanent transportation segment identifier is attractive, but the need to

148   add new transportation segments to accommodate other applications or to reflect changes

149   in infrastructure can create problems. Consider the case of a road segment (Segment_A)

150   with an assigned permanent identifier, as illustrated in Figure 1. A new road

151   (Segment_B) is built

152   which intersects the old

153   road segment part way

154   along its length. In order

155   to maintain network

156   topology, the old road

157   segment must be split and a

158   node established where the

Figure 1 - Intersecting Road Segments

159   new road intersects. The identifier for the old road segment is no longer valid. It must be

160   retired and three new identifiers created: one for the new intersecting road (Segment_B)

161   and one for each new segment (Segments_AA and AB) of the (now split) old road

162   segment. Recording, disseminating, and applying these transactions could become

163   prohibitively complex or time-consuming, both for the database developer and for users

164   trying to incorporate the updated information into their own application database.

165   In summary, the growing needs of users make the argument for constructing an NSDI

166   framework transportation data layer(s) a compelling one. Also, all users will benefit if the

167   investments in high quality transportation information being made by many units of state

168   and local government can be incorporated. The related technical requirements present a

169   challenge in the development of standards, technology and procedures which will be

170   needed in order to accomplish this task.

171   1.2   Conventions used in this Standard

172   The following conventions for forms of values for data elements are used in this Standard:

173   1.2.1   Calendar Dates

174   Values for day and month of year, and for years, shall follow the calendar date convention

175   (general forms of YYYY for years; YYYYMM for month of a year (with month being

176   expressed as an integer), and YYYYMMDD for a day of the year) specified in American

177   National Standards Institute, 1986, Representation for calendar date and ordinal date for

178   information interchange (ANSI X3.30-1985): New York, American National Standards

179   Institute (adopted as Federal Information Processing Standard 4-1).

180   1.2.2   Latitude and Longitude

181   Values for latitude and longitude shall be expressed as decimal fractions of degrees.

182   Whole degrees of latitude shall be represented by a two-digit decimal number ranging

183   from 0 through 90. Positive numbers indicate North latitude; negative numbers indicate

184   South latitude. Whole degrees of longitude shall be represented by a three-digit decimal

185   number ranging from 0 through 180. Positive numbers indicate West longitude; negative

186   numbers indicate East longitude. When a decimal fraction of a degree is specified, it shall

187   be separated from the whole number of degrees by a decimal point. This form is specified

188   in American National Standards Institute, 1986, Representations of Geographic Point

189   Locations for Information Interchange (ANSI X3.61-1986): New York, American

190   National Standards Institute.

191   1.2.3   Numeric Values

192   Values for distance and other measures are specified as a specific number of characters;

193   this specification includes characters for plus (+) and minus (-) signs and decimal points (.)

194   whenever appropriate. Many users will operate applications which store, compute, or

195   analyze these attributes in a variety of "numeric" field formats, but they should be able to

196   import and export these standardized data in the character field formats specified.

197   1.3 Justification

198   1.3.1   Objective

199   The objective of this content standard is to specify methods for identifying linear geo-

200   spatial features that can be implemented within existing data structures without some of

201   the topological problems cited above. Furthermore, the proposed standard should allow

202   users to create customized topological networks from the reference segments without

203   modifying the properties of the reference segments themselves. Successful achievement of

204   this objective will facilitate transactional updates to framework transportation databases by

205   allowing new transportation features to be added without changing existing transportation

206   segments. The standard should define a transportation segment in such a way that it is

207   independent of cartographic representation – irrespective of scale, attributes which can

208   change over time, and network topology. Each defined transportation segment can then

209   be assigned a unique identifier that does not need to be modified for different applications

210   or for additions of new transportation features.

211   Establishment of stable transportation segment identifiers will facilitate the exchange of

212   information between databases; e.g., improved geo-spatial coordinates, feature attributes

213   like road names, or controls to various linear referencing methods like beginning and

214   ending mile points, or low and high address values.

215   The **NSDI Framework Transportation Identification Standard** defines the collection

216   of objects which serve as the basis for transferring information among different networks,

217   higher level linear referencing systems, and cartographic representations of roads. The

218   standard relates multiple cartographic and topological network data base representations

219   to uniquely identified transportation segments in the real world, and provides the domain

220   for transferring application attributes across linear referencing and cartographic systems.

221   The model consists of a set of one-dimensional **Framework Transportation Segments**

222   **(FTSeg)** that have zero-dimensional **Framework Transportation Reference Points**

223   **(FTRP)** at their termini. FTRP and FTSeg are highly stable, unambiguously identified,

224   and recoverable in the field.

225   The standard is not intended to be a geodetic or linear datum. It contains no specification

226   for either coordinate or linear measurement accuracy. However, the standard does

227   provide a structure for accommodating a linear datum by including coordinates and length

228   measures as attributes, and by requiring accuracy statements whenever such measures are

229   specified. This enables users to assess the suitability of the geometry or attributes from

230   one or more transportation databases for their particular application(s).

231   1.3.2   Scope

232   The NSDI Framework Transportation Identification Standard is being proposed as an

233   "FGDC data content standard." It includes both standards for assigning and reporting

234   identification codes as well as guidelines for data capture under the classification of a

235   process standard.

236   **Part II** of this document provides a standard for identifying physical transportation

237   segments that are temporally stable and independent of any cartographic representation,

238   scale, level of detail, or network application. Any transportation databases considered to

239   be compatible with the NSDI transportation framework layer must conform to this

240   standard.

241   The data content standard includes a mandatory set of attributes for each Framework

242   Transportation Segment (FTSeg), and a format for a unique identification code to be

243   assigned to each identified segment. Each FTSeg begins and ends at a Framework

244   Transportation Reference Point (FTRP); mandatory attributes and an identification code

245   for each FTRP are also specified. Part II also specifies a process for assigning, modifying

246   and recording FTRP and FTSeg identification codes, and proposes a national registry for

247   their identification.

248   The standard articulated here can be extended in the future to cover other transportation

249   features that could be represented as networks including railroads, commercial waterways,

250   pipelines, and public transit guide ways. Other network layers will require different

251   process standards for assigning and recording identification codes. These additional

252   process standards are not included as part of this document.

253   **Part III** of this document is made up of technical appendices, including references, a

254   glossary of relevant terms, examples, and further information. It includes guidelines for

255   selecting and locating the reference points of appropriate transportation segments, as well

256   as other implementation procedures. The user of this document need not follow the

257   guidelines to be in conformance with the standard.

258   1.3.3   Applicability

259   This proposed standard will have widespread applicability for public-sector and

260   commercial database developers and data users, because there are no national standards

261   for identifying, segmenting, or representing transportation segments in digital geo-spatial

262   databases. Each database developer segments transportation networks to satisfy his/her

263   specific application needs; however, the segmentation may not be appropriate for other

264   applications. Furthermore, there is no standard approach for documenting the relationship

265   between a digitized transportation segment and the physical transportation feature that it

266   represents. Consequently, the exchange of attribute information between two different

267   transportation databases representing the same geographic area is difficult, time

268   consuming and error prone.

269   The proposed national standard for identifying and documenting transportation segments

270   will facilitate data exchange among different users by providing well defined, common

271   reference segments that are tied to the physical transportation feature, rather than to any

272   cartographic or network abstraction of that feature. It will allow users to create

273   customized topological networks from the reference segments without modifying the

274   properties of the reference segments themselves, and to make transactional updates to

275   framework transportation databases.

276   1.3.4   Consistency with Other Relevant Standards & Policies

277   1.3.4.1   FGDC Standards

278   1.3.4.1.1 Spatial Data Transfer Standard (SDTS)

279   The purpose of the SDTS is to promote and facilitate the transfer of digital spatial data

280   between dissimilar GIS software packages, while preserving information meaning and

281   minimizing the need for information external to the transfer. Implementation of SDTS is

282   of significant interest to users and producers of digital spatial data because of the potential

283   for increased access to and sharing of spatial data, the reduction of information loss in data

284   exchange, the elimination of the duplication of data acquisition, and the increase in the

285   quality and integrity of spatial data. SDTS is neutral, modular, growth-oriented,

286   extensible, and flexible -- all characteristics of an "open systems" standard.

287   The SDTS includes conceptual models and definitions for spatial objects; a partial glossary

288   of geo-spatial features; and standardized files structures and encoding specifications. The

289   SDTS accommodates all forms of spatial data representation including raster, vector and

290   graphical objects. In its general form, it is too complex to be implemented within a single

291   translation software program. Instead, more restrictive SDTS profiles are being

292   developed to transfer a specific type of spatial data. To date, profiles have been developed

293   for planar topological vector data, raster data, and high precision point data. For further

294   information see http://mcmcweb.er.usgs.gov/sdts/.

295   1.3.4.1.2 SDTS Transportation Network Profile (TNP)

16

296   A draft profile was developed in 1995 for transferring non-planar vector data,

297   characteristic of transportation networks. However, the profile was not submitted for

298   formal adoption due to a number of unresolved issues. This standard is expected to

299   address most of these issues and thereby enable resumption of the TNP development. For

300   further information see: http://www.bts.gov/gis/reference/tnp_11.html.

301   1.3.4.1.3 Facility Identification Data Standard (proposed by the FGDC Facilities Working

302   Group)

303   The proposed "FGDC Data Content Standard for Location and Identification of Facilities"

304   is intended to develop a Facility Identification data standard that supports identification of

305   place-based objects generally known as facilities. The draft standard incorporates

306   identification of transportation objects which are defined as "Framework Transportation

307   Segments." The proposed identifiers are defined and derived inconsistently in the two

308   drafts; the Chair of the Ground Transportation Subcommittee has noted this in written

309   comments. The Ground Transportation Subcommittee and the Facilities Working Group

310   will work together to define a consistent identifier or to appropriately delineate the scope

311   of each standard. For further information see

312   http://www.fgdc.gov/standards/status/sub3_3.html .

313   1.3.4.1.4 Ground Transportation Data Content Standard (proposed by the FGDC

314   Facilities Working Group)

315   The proposed "Data Content Standard" is intended to provide a common set of

316   entity/attribute/domain definitions for transportation features. The Framework

317   Transportation Identification Standard will provide the foundation on which transportation

318   features in this content standard will be defined, and these two efforts will be closely

319   coordinated. (See http://www.fgdc.gov/standards/status/textstatus.html)

320   1.3.4.1.5 Address Content Standard (proposed by the FGDC Cultural and Demographic

321   Subcommittee)

322   The proposed "Address Content Standard" is intended to provide consistency in the

323   maintenance and exchange of address data and enhance its usability.

324   This proposed standard will provide semantic definitions for components determined by

325   the participants to be integral to the creation, maintenance, sharing, usability, and

326   exchange of addresses and/or address lists. Within this scope, addresses are broadly

327   defined as locators to places where a person or organization may reside or receive

328   communications, but excluding electronic communications. An address list consists of one

329   or more addresses. The "Address Content Standard" will additionally define an

330   entity-relationship model for address data. The "Transportation Identification Standard"

331   will establish criteria for defining and constructing transportation centerline networks to

332   which address ranges and other linear referencing methods may be appended. The

333   "Transportation Identification Standard" development is being coordinated with the

334   address content standard to ensure they are compatible.   (See

335   http://www.fgdc.gov/standards/status/sub2_4.html .)

336   1.3.4.1.6 National Hydrography Dataset

337   The National Hydrography Dataset project aims to produce a well documented,

338   maintainable and nationally consistent hydrography dataset. This database is also a non-

339   planar topological network, and many of the same concepts will be used in the

340   Transportation Identification Standard. However, the Transportation Identification

341   Standard includes certain enhancements to handle the non-dendritic properties of

342   transportation networks and to allow multiple data developers to contribute and enhance

343   transportation data for the same geographic area. For further information see

344   http://nhd.usgs.gov .

345   1.3.4.2   Other Organizations

346   1.3.4.2.1 Vector Product Format

347   VPF is a standardized format, based on a geo-relational data model, developed by the

348   Defense Mapping Agency (now known as the National Imagery and Mapping Agency

349   (NIMA)), for large geographic databases. VPF is designed to be compatible with a wide

350   variety of applications and products, and allows application software to read data directly

351   from various storage media without prior conversion to an intermediate form. VPF was

352   primarily created as a storage and transfer format for cartographic data developed,

353   maintained, and used by the military. It does not address the specific requirements of non-

354   planar topological networks, nor does it address issues of data enhancement from multiple

355   contributors. Databases constructed using the Transportation Identification Standard

356   should be easily convertible to VPF.   For further information see

357   http://164.214.2.59/vpfproto/index.htm .

358   1.3.4.2.2 Other Models and Standards: GIS-T, Intelligent Transportation Systems, and

359   GDF

360   The **GIS for Transportation** (GIS-T) research community has been investigating

361   transportation data models for several years, and several candidate conceptual models

362   have been proposed. The **Intelligent Transportation Systems** (ITS) movement has also

363   addressed interoperability across data bases. For the most part, however, these candidate

364   models are unfamiliar to many of the spatial database developers who are currently

365   engaged in NSDI Framework activities.

366   This proposed standard is intended to use terminology and concepts which are entirely

367   consistent with the GIS-T work, the ITS work, and other transportation conceptual

368   models described elsewhere. At the same time the proposed standard is focused on

369   objectives which are more limited than those advanced by either of these two efforts.

370   These limitations are intended to make the proposed NSDI standard easier to understand

371   and to implement across multiple database environments. Further information relating to

372   GIS-T can be obtained at http://www4.nas.edu/trb/crp.nsf/All+Projects/NCHRP+20-27(2)

373   . Further information relating to ITS can be obtained at

374   http://itsdeployment.ed.ornl.gov/spatial/files/ITSDEF.htm .

375   **Geographic Data Files** format (GDF) is a European standard that is used to describe and

376   transfer road networks and road related data. GDF provides rules of how to capture the

377   data, and how the features, attributes and relations are defined. GDF has been developed

378   in a European project called EDRM (European Digital Road Map). Its primary use will be

379   for car navigation systems, but it is very usable for many other transport and traffic

380   applications like Fleet Management, Dispatch Management, Traffic Analysis, Traffic

381   Management, Automatic Vehicle Locations etc.

382   GDF version 3.0 has been released and issued to CEN (Central European Normalization)

383   for the voting procedure. After the voting GDF will become the only CEN accepted

384   standard for digital road networks; ISO standardization of GDF is expected in 2000. For

385   further information see http://www.ertico.com/links/gdf/gdf.htm .

386   1.3.5   Standards Development Procedures

387   The FGDC initiated work on this proposed standard in December 1997 through a data

388   developers' workshop held to discuss the topic. Workshop participants presented

389   examples of their work on Framework projects, and articulated many common elements.

390   For further information see http://www.fgdc.gov/framework/page04.html .

391   The first draft of this standard was prepared during the summer and early fall of 1998, for

392   the review of a technical committee called together at the invitation of the Chair of the

393   FGDC Ground Transportation Subcommittee. This is a third draft version, which

394   incorporates comments collected during much of 1999, and is currently in Step 5 (Review

395   Working Draft) of the FGDC Standards Reference Model.

396   1.3.6   Maintenance Authority

397   The current maintenance authority for the standard is the United States Department of

398   Transportation (USDOT.) Questions concerning the standard should be addressed to:

399   Mark Bradford, c/o USDOT/BTS K-40, Room #3430, 400 7th St. SW, Washington DC

400   20590. Copies of this publication are available from the FGDC Secretariat, in care of the

401   U.S. Geological Survey, 590 National Center, Reston, Virginia 20192; telephone (703)

402   648-5514; facsimile (703) 648-5755; Internet (electronic mail) fgdc@www.fgdc.gov .

403   The text also is available at the FGDC web site http://www.fgdc.gov/standards/ .

404   2   **The Framework Transportation Identification Standard**

405   2.1   Overview

406   A key piece in creating a national standard for geospatial data representing transportation

407   networks is the development, implementation, and general acceptance of a transportation

408   identification standard. The function of such a data standard is to enable database

409   developers to transact updates and to exchange information by defining unique and

410   relatively stable transportation reference points and segments that can be assigned

411   permanent feature identifiers.

412   2.2   Relationships between the "Real World", Cartography, and Networks, and the

413   Framework Transportation Identification Standard

414   A useful transportation identification standard must successfully address several issues

415   without causing unreasonable extra burden to either database developers or users. First,

416   the standard must be useful in representing the physical or real-world domain of

417   transportation features. Second, the standard must be useful in fulfilling the wide variety

418   of mapping requirements of users. Third, the standard must support a large number of

419   different network applications; for example: *address geo-coding, network pathfinding,*

420   *vehicle and incident location,* and *highway facility management.* Each of these

421   applications typically segments the network in different ways.

422   2.2.1   Physical ("Real-World") Domain

423   Transportation features in the physical or real-world domain consist of tangible objects

424   such as *roads, bridges, railroad tracks, and intersections*. At a minimum, representations

425   of physical objects require information to enable someone to locate and recognize them in

426   the real world. Location information may be purely descriptive (e.g. *"the intersection of*

427   *the centerlines of 7th & D Streets, SW in Washington, DC"*), or the description may be

428   supplemented by measurements that can be repeated in the field (e.g., GPS coordinates).

429   This Standard supports the unambiguous identification of unique real-world features by

430   requiring some descriptive information and some quantitative positional information about

431   each feature, and by allowing its augmentation with other information when users make it

432   available.

433   2.2.2   Cartographic Domain

434   Cartographic objects are used to represent real world features on a map. In vector-based

435   GIS, real-world objects are typically displayed as *points* (or *symbols*), *lines,* or *polygons*.

436   Transportation networks are displayed using points and strings of line segments. While

437   there is no *a priori* requirement that cartographic points and strings must be topologically

438   connected, most GIS software build topology to facilitate spatial and network

439   computations. However, the topology created by the GIS may not be the same as the

440   topology specified in the transportation network (e.g., a node may be placed where two

441   links cross but don't intersect).

442   Planar coordinates define the relative locations and shapes of cartographic objects on a

443   two-dimensional plane. These coordinates are typically transformations of real world

444   geographic coordinates (e.g., given a specified geodetic datum and projection). However,

445   the relative accuracy of each plotted point is subject to various errors (e.g., physical

446   location measurements, digitizing accuracy, and distortions caused by planar projections

447   of three-dimensional distances). Consequently, there are differences in both the location

448   and distance measurements between the real world and a map.

449   This Standard does not attempt to address these cartographic differences; nor does it

450   attempt to reconcile the differences that exist among multiple cartographic representations

451   of the same real-world features. However it does propose a standard method for

452   specifying real-world features, so that users of different cartographic representations can

453   more easily exchange updates to both geometric and tabular information.

454   2.2.3   Network Domain

455   Network objects consist of *links* and *nodes,* which together form the *network*; these

456   objects are inherently topological. Transportation networks provide information on the

457   feasible paths between specified locations, and on decision points along those paths.

458   Origins and destinations are assumed to be specific as to location, but the location of a

459   decision point need not exist in the physical world. A network does not require

460   cartographic coordinates; rather, only a set of choices need be identified at each decision

461   point (e.g., the decision point to drive or take transit can be made at any time or place

462   prior to the decision to use transit).

463   Once a network has been created, other transportation application layers can be built upon

464   it, including *identified routes, linear referencing methods*, and *linearly referenced points*

465   and *linear events*. All of these application layers can ultimately be mapped back to the

466   transportation reference points and segments through the specific network links and nodes

467   on which these application layers were built. Geometric shape is not a required part of

468   network *links, routes,* or *linear events*. Any of these may be constructed without

469   coordinates. All that is required to construct the network layer (links and nodes) is the

470   topological connections of the segments. Construction of routes and linear referencing

471   methods is accomplished through an ordered listing of the links (or parts of links) that

472   comprise each route. *EXAMPLE: Emergency service authorities may wish to define a*

473   *"Road-Name" Route to support vehicle dispatch. They can do so by defining the*

474   *"official" road name as an attribute associated with all or a part of each link. The*

475   *ordered listing of all the links associated with each "official" road name will define the*

476   *"Road-Name" Route.*

477   This Standard does not attempt to define topological relationships within any one or more

478   networks, but does provide to the users of multiple networks a stable identifier for real-

479   world features.

480   2.3   Components of the Transportation Identification Standard[1]

481   2.3.1   **Framework Transportation Segment Reference Point (FTRP)** – *The*

482   *specified location of a (required) endpoint of a Framework Transportation*

483   *Segment (FTSeg), or an (optional) reference point offset along the length of the*

484   *FTSeg, on a physical transportation system.*

485   2.3.1.1   The FTRP Table

486   An FTRP database record has a unique key consisting of fields 1, 2 and 3 (emboldened);

487   values are required for all fields, except those designated "optional" or conditionally

488   required. An FTRP record contains the following information[2]:

---

[1]The abbreviations "FTRP" and "FTSeg" are used in this document as singular or plural nouns. When used singularly they are modified by "an" rather than "a" as a matter of convention.

[2]The NSDI Framework Transportation Identification Standard is being proposed as an "FGDC data content standard." This proposal does not include standards for formatting or encoding the information described in this Table or in any other tables.

#	FTRP Table Field-Name	Description & Format/Domain
489		
1	**Authority-ID**	Permanent and unique identifier of the organization which created this record. This ID may differ from the ID of the authority which created the original FTRP database entry or subsequent records. Format specified in Section 2.6
2	**FW-Transportation-Segment-Reference-Point-ID**	Permanent and unique identifier for the FTRP Format specified in Section 2.6
3	**Date**	Date of creation of the record Format YYYYMMDD
4	Location-Description	Unambiguous description of the FTRP that makes it field-recoverable Free text: 255 characters or less
5	FTRP-Feature-Type *(Optional)*	Format: Free text of ten characters or less; Domain declared by the authority
6	Latitude	Angular distance measured on a meridian north or south from the equator. (NAD83) Format: +/- DD.dddddd; 10 character Decimal degrees Range: +/-0 to 90.000000
7	Longitude	Angular distance between the plane of a meridian east or west from the plane of the prime meridian. (NAD83) Format: +/- DDD.dddddd; 11 character Decimal degrees Range: +/-0 to 180.000000

The line numbers in the left margin: 489, 490, 491, 492, 493, 494, 495, 496.

497	8	Horizontal-Accuracy-Measurement-Method	Three-character code which describes the derivation of the horizontal position, and which allows the user to assess the accuracy and precision of the FTRP latitude and longitude:
			100 = Derived from stationary GPS measurement, with no differential correction
			*1xx = Stationary GPS measurement -differentially corrected to "xx" meters; e.g., **105** = differential correction to 5 meter accuracy
			200 = Derived from mobile GPS measurement, without differential correction
			*2xx = Derived from mobile GPS measurement, differentially corrected to "xx" meters
			300 = Derived from non-GPS survey methods - accuracy unknown
			*3xx = Derived from non-GPS survey methods - accuracy certified to "xx" meters
			400 = Digitized from digital orthoimagery - Source scale unknown
			4xx = Digitized from digital orthoimagery - Source scale of image in 000's; e.g. 412 =1:12,000 scale source digital orthophotos.
			5xx = Digitized from paper map sources larger than 1:100,000 scale - Source scale in 000's e.g. 524 = 1:24,000 scale topographic maps
			600 = Source scale 1:100,000 digital data - e.g., TIGER/Line or DLG
			6xx = Digitized from paper map sources smaller than 1:100,000 scale - Source scale in 100,000's e.g. 625 = 1:250,000 scale maps
			900 = Other
			* – "xx" should be "01" when accuracy is certified to 1 meter or less.

29

498	9	Horizontal-Accuracy *(Optional and Recommended)*	Maximum estimated error in horizontal location Format: MMM.mm; 6 characters, indicating "plus or minus" a number of meters
499	10	Elevation *(Optional and Recommended)*	Elevation above/below sea level Format: +/- MMM.mm; 7 character decimal meters, indicating "plus or minus" a number of meters
500	11	Vertical-Accuracy-Measurement-Method *(Required if Elevation is not "blank")*	Three-character code which describes the derivation of the elevation, and which allows the user to assess the accuracy and precision of the FTRP elevation: **100** = Derived from stationary GPS measurement, with no differential correction ***1xx** = Stationary GPS measurement -differentially corrected to "xx" meters; e.g., **105** = differential correction to 5 meter accuracy **200** = Derived from mobile GPS measurement, without differential correction ***2xx** = Derived from mobile GPS measurement, differentially corrected to "xx" meters **300** = Derived from non-GPS survey methods, accuracy unknown ***3xx** = Derived from non-GPS survey methods, accuracy certified to "xx" meters **800** = Derived from a Digital Elevation Model **900** = Other ** – "xx" should be "01" when accuracy is certified to 1 meter or less.*
501	12	Vertical-Accuracy *(Optional and Recommended)*	Maximum estimated error in vertical location Format: MMM.mm; 6 characters, indicating "plus or minus" a number of meters
502	13	Status	**P** = Proposed; **A** = Active; **R** = Retired

503   2.3.1.2   Description of FTRP Table Elements

504   Fields emboldened above are "key" fields – **Authority, FTRP-ID,** and **Date**; taken

505   together, they make up a unique key for each record in the FTRP Table. They are

506   required so that a record which describes a specific FTRP can be improved over time.

507   Multiple authorities and data users will recognize, access, use, and archive FTRP records

508   that represent a "real world" location, as identified by a particular authority at a particular

509   point in time.

510   The required textual **Location-Description** must be sufficient to allow all users to

511   unambiguously identify that FTRP in the field. However changes in applications and

512   technology will allow the multiple authorities to refine over time the specifics of the

513   Location-Description, coordinates, and accuracy Description. The use of a multi-part key

514   provides relative permanence to the FTRP-ID, while allowing the creation of additional

515   database records which can reflect these refinements. As a result, users will be able to

516   embed FTRP within their own data structures, and acquire refined information about them

517   over time (as it is made available by multiple authorities). At the same time they will not

518   have to expend resources on updating internal references to this primary key.

519   The optional **FTRP-Feature-Type** allows the authority to provide information about the

520   type of point feature designated as the FTRP. Each authority which chooses to use this

521   field must reference the domain of valid attribute values in the NSDI Framework

522   Authority Index (See Section 2.8). The Authority-Information field of this record should

523   contain a brief reference to the authority's use of the FTRP-Feature-Type, and should

524   direct the user to the source of metadata about this attribute.

525   The **Latitude**, **Longitude,** and **Horizontal-Accuracy- Measurement-Method** of each

526   FTRP must be provided. **Horizontal-Accuracy** is optional, but should be provided when

527   the Authority believes accuracy to be +/- 1 meter (or better). When the **Elevation** is not

528   blank, a valid **Vertical-Accuracy-Measurement-Method** code is also required.

529   **Vertical-Accuracy** is optional, but should be provided when the Authority believes

530   accuracy to be +/- 1 meter (or better). The measurement method codes are intended to

531   allow data users to assess the accuracy and precision of the FTRP position without

532   requiring authorities to provide a quantitative error estimate.

533   A required **Status** code allows authorities to design and share/compare "proposed" FTRP

534   with other interested authorities before coming to agreement on their designation. Also

535   retention of records coded as "retired" enables users to update their databases after FTRP

536   have been retired because of physical re-alignments or reconciliation of duplicate records.

537   2.3.2   **Framework Transportation**

538   **Segment (FTSeg)** – *A specified*

539   *directed path between two*

540   *Framework Transportation*
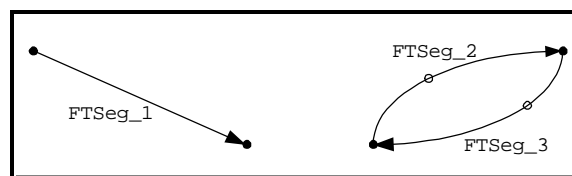
Figure 2 – Unique pathways connecting two FTRP

541   *Segment Reference Points along a physical transportation system that identifies*

542   *a unique segment of that system.*

543   FTSeg have no explicit geometry other than the locations of associated reference points

544   (FTRP). Most FTSeg terminate at two FTRP. However, cul-de-sac loops may consist of

545   FTSeg which originate and terminate at the same FTRP, and FTSeg may have other FTRP

546   offset along their length. FTSeg should be depicted either by straight lines connecting two

547   FTRP or by curved lines (if two or more FTSeg terminate at the same two FTRP.)[3]

548   2.3.2.1   Requirements for FTSeg

549   2.3.2.1.1 FTSeg must represent a component of the transportation network, with

550   unambiguous beginning and end points (FTRP) that can be initially located and

551   subsequently recovered in the field.

552   2.3.2.1.2 FTSeg must be independent of any particular cartographic display or analytical

553   network. The nodes of a particular analytical network may be useful in defining

554   the FTRP which begin and end at an FTSeg, but other points may serve as well.

---

[3]Guidelines for cartographic representation of FTRP and FTSeg are provided in Section 1.1 of Informative
Appendix C.

555   2.3.2.1.3 An FTSeg may not cross the boundary of a State, territory or equivalent

556   jurisdiction; therefore the maximum length of any FTSeg is the span of the

557   jurisdiction in which it lies.

558   2.3.2.1.4 FTSeg must be stable over time. New links are routinely added, and existing

559   links are routinely split in many transportation networks.   New links may

560   represent a newly constructed road, or they may represent a set of features (e.g.,

561   driveways) needed to support a particular application. In either case, existing

562   FTSeg should not be changed in order to handle these additional links. In some

563   rare instances it may be necessary and permissible to modify an existing FTSeg.

564   The specific update procedures needed to handle such situations are detailed in

565   Part 3 of this document.

566   2.3.2.2   The FTSeg Table

567   An FTSeg database record has a unique key consisting of fields 1, 2 and 3 (emboldened);

568   all fields are required, unless otherwise indicated. An FTSeg record contains the following

569   information:

#	FTSeg Table Field-Name	Description & Format/Domain
1	**Authority-ID**	Permanent and unique identifier of the organization which created the record. This ID may differ from the ID of the authority which created the original FTSeg database entry or subsequent records. Format specified in Section 2.6

570

571

572	**2**	**FW-Transportation-Segment-ID**	Permanent and unique identifier for the FTSeg Format specified in Section 2.6
573	**3**	**Date**	Date of creation of the record Form YYYYMMDD
574	4	From-End-Point	Unique identifier of the FTRP at which this FTSeg begins Format specified in Section 2.6
575	5	To-End-Point	Unique identifier of the FTRP at which this FTSeg ends Format specified in Section 2.6
576	6	Path-Description	Unambiguous description of the path of this FTSeg, which is unique with respect to any other FTSeg which connects the same two End-points. Free text: 255 characters or less
577	7	Intermediate-Point *(Required when Applicable)*	Identifier of the FTRP located at an intermediate point on the FTSeg for the purpose of distinguishing this FTSeg from (one or more) other FTSeg which share the same end points. Format specified in Section 2.6
578	8	FTSeg-Feature-Type *(Optional)*	Format: Free text of ten characters or less; Domain declared by the authority
579	9	State	Two-character code indicating the State, territory or equivalent entity within which the transportation segment begins and ends Codes are specified in FIPS 6-4
580	10	Length *(Optional and Recommended)*	Measured length of the segment Format: MMMMMM.mm; 9 character decimal meters

35

581	11	Length-Accuracy-Measurement-Method *(Required if Length is not "blank")*	Three-character code which describes the derivation of the Length measurement, and which allows the user to assess the accuracy and precision of the FTSeg length: **100** = Survey measurement **210** = Measured by a distance measurement device; e.g., "fifth wheel" **220** = Measured by an automobile odometer or analogous device **310** = Computed from a digital vector database scaled at larger than 1:12000 **320** = Computed from a digital vector database scaled at from 1:12000 to 1:100,000 **330** = Computed from a digital vector database scaled at smaller than 100,000 **900** = Other
582	12	Status	**P** = Proposed; **A** = Active; **R** = Retired

583   2.3.2.3   Description of FTSeg Table Element

584   Fields emboldened above are "key" fields – **Authority, FTRP-ID,** and **Date**; taken

585   together, they make up a unique key for each record in the FTSeg Table. These fields are

586   required in order that FTSeg records can be improved by multiple authorities over time,

587   archived, and accessed by different users, just as FTRP records can be. The **From-End-**

588   **Point** and **To-End-Point** values are required in order to unambiguously delineate each

589   FTSeg. (Refer to description **Intermediate-Point**, below.)

590   An FTSeg record must include an **Intermediate-Point** consisting of a single FTRP-ID

591   whenever the FTSeg in question has the same From-End-Point and To-End-Point as one

592   or more other FTSeg. The additional FTRP identified in this field should represent an

593   intermediate point along the FTSeg, judiciously selected in order to assure that the

594   multiple FTSeg which terminate at the same FTRP are unambiguously differentiated.

595   Pairs of FTSeg for which the To-End-Point and From-End-Point are reversed will occur

596   routinely; they must be assigned different unique FTSeg identifiers, but need not have

597   Intermediate-Points.

598   A textual **Path-Description** that is sufficiently complete as to allow other users to

599   unambiguously identify the course of the FTSeg in the field is also required.

600   The optional **FTSeg-Feature-Type** allows the authority to provide information about the

601   type of linear feature designated as the FTSeg. Each authority which chooses to use this

602   field must reference the domain of valid attribute values in the NSDI Framework

603   Authority Index (See Section 2.8). The Authority-Information field of this record should

604   contain a brief reference to the authority's use of the FTSeg-Feature-Type, and should

605   direct the user to the source of metadata about this attribute.

606   A required **State** code allows authorities and users to more easily identify records of

607   possible interest. Because FTSeg may not cross state boundaries, in most cases the code

608   should indicate the State, territory or equivalent entity within which the transportation

609   segment begins and ends. If the FTSeg lies precisely along a boundary line between two

610   States, territories or equivalent entities, these entities should derive a shared business rule

611   for coding the FTSeg.

612   **Length** and **Length-Accuracy-Measurement-Method** are optional. The accuracy

613   description codes are intended to allow data users to assess the precision of the FTSeg

614   length without requiring authorities to provide a quantitative error estimate.

615   A required **Status** code allows authorities to design and share/compare "proposed" FTSeg

616   with other interested authorities before coming to agreement on their designation. Also
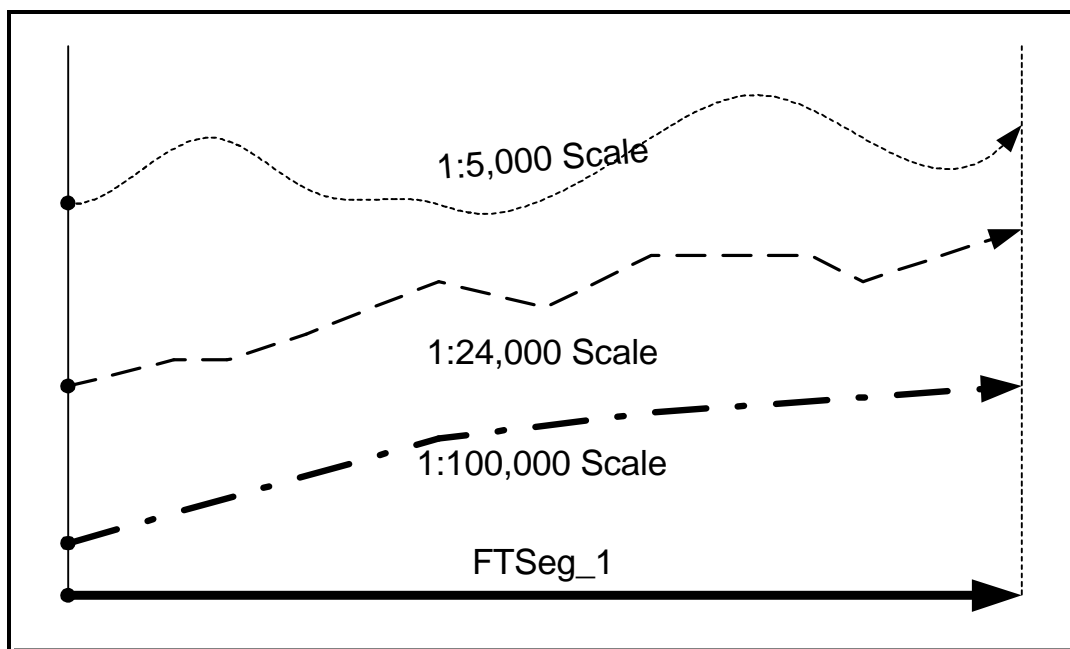
Figure 3 - Representation of an FTSeg and different scales

617   retention of records coded as "retired" enables users to update their databases after FTSeg

618   have been retired because of physical re-alignments or reconciliation of duplicate records.

619   While FTSeg have no explicit geometry themselves, they may be represented by a variety

620   of cartographic line segments depicting their shape and location on the earth. The line

621   segments may be more or less complex, reflecting different scales of resolution, map

622   projections, or structural detail.

623   2.4   Connectivity of Framework Transportation Segments

624   FTSeg may be used to construct topological networks, but do not represent a topological

625   network by themselves. FTRP are required to establish connections among two or more

626   FTSeg, either at their termini and/or at some offset along their length. FTRP can

627   optionally be placed along FTSeg in locations at which no connectivity occurs. The

628   structure in which these relationships are established is described below.

629   2.4.1   The Connectivity Table

630   All topological relationships between entities in the data standard are described in the

631   Connectivity Table. At least one record must exist for each FTSeg. At least one record

632   must exist for each FTRP, even if it occurs at the terminus of an FTSeg or at some other

633   location at which no connectivity exists; e.g., a bridge or a railroad crossing. More than

634   one record will exist for each FTRP at which connectivity occurs. The Connectivity Table

635   supports a "one-to-many" relationship between FTRP and the number of connections

636   made at each, so is in the form of an unordered list:

#	Connectivity Table Field Name	Description & Format/Domain
1	Authority-ID	Permanent identifier of the organization which created this record. This ID may differ from the ID of the authority which created the original FTRP database entry or subsequent records. Format specified in Section 2.6
2	FW-Transportation-Segment-Reference-Point-ID	Permanent and unique identifier for the FTRP Format specified in Section 2.6
3	Date	Date of creation of this record Format YYYYMMDD
4	FTSeg-ID	Unique identifier of an FTSeg along which this FTRP falls. Format specified in Section 2.6
5	FTSeg-Offset-%	Percentage offset from the FTSeg From-End-Point at which this FTRP falls A positive decimal number greater than or equal to "0" and less than or equal to "100.0000". Format: 000.0000; 8 characters

The row labels 637, 638, 639, 640, 641, 642 appear in the left margin corresponding to the header row and rows 1 through 5 respectively.

643	6	Offset-%-Accuracy-Description	Three-character code which describes the derivation of the FTSeg-Offset-% measurement, and which allows the user to assess the accuracy and precision of the offset along the FTSeg:
			100 = Survey measurement
			210 = Measured by a distance measurement device; e.g., "fifth wheel"
			220 = Measured by an automobile odometer or analogous device
			310 = Computed from a digital vector database scaled at larger than 1:12000
			320 = Computed from a digital vector database scaled at from 1:12000 to 1:100,000
			330 = Computed from a digital vector database scaled at smaller than 100,000
			900 = Other
644	7	Status	**P** = Proposed; **A** = Active; **R** = Retired

645   2.4.2   Description of Connectivity Table Elements

646   **FTRP-ID, Authority,** and **Date** are required so that each record indicates what authority

647   established the placement of an FTRP along an FTSeg, and when.

648   An **FTSeg-ID** indicates the segment along which the FTRP lies. The **FTSeg-Offset-%**

649   indicates the FTRP's placement along the FTSeg, and the **Offset-%-Accuracy-**

650   **Description** codes are intended to allow data users to assess the precision of the FTSeg-

651   Offset-% without requiring authorities to provide a quantitative error estimate.

652   A required **Status** code allows authorities to design and share/compare "proposed" FTRP

653   with other interested authorities before coming to agreement on their designation. Also

654   retention of records coded as "retired" enables users to update their databases after FTRP

655   have been retired because of physical re-alignments or reconciliation of duplicate records.

656   2.4.3   Categories of Connectivity[4]

657   2.4.3.1   Two or more FTSeg are said to be

658   *terminally* connected if they share

659   a common FTRP at their termini.   **Figure 4** – Terminal connectivity of two
FTSeg at FTRP_1
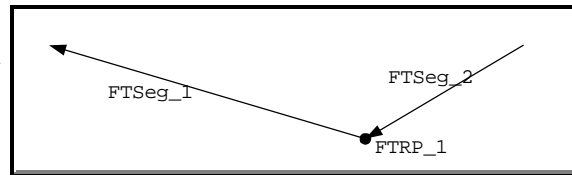
660   The terminal connectivity

661   illustrated in Figure 4 is implemented in the Connectivity Table in two records

662   for `FTRP_1`; one indicates that `FTRP_1` is offset 0% of the length of

663   `FTSeg_1`. The second record indicates that `FTRP_1` is offset 100% of the

664   length of `FTSeg_2`. The FTSeg-Offset-% in such records will always by "0%"

665   or "100%." The Table would contain one record for any additional FTSeg

666   which was terminally connected at `FTRP_1`.

---

[4]Previous drafts of the Standard defined two connectivity types; this version introduces a third connectivity type.
The definition of *explicit connectivity* is the same as in previous drafts. The definition of *implicit connectivity* has changed
from that used in previous drafts, and the definition used formerly applies in this draft to *terminal connectivity*.

667   2.4.3.2   Segments are said to be *explicitly* connected whenever:

668   2.4.3.2.1   there are two or more records in the Connectivity Table which describe the

669   same FTRP, and

670   2.4.3.2.2   at least one of the records indicates that the FTRP falls at a termini of an

671   FTSeg, and

672   2.4.3.2.3 at least one other record indicates that the FTRP lies on an FTSeg at a point

673   other than a terminus.

674   In Figure 5, P3 is an end

675   point of FTSeg_2 and

676   P4 is an end point of

677   FTSeg_3 and FTSeg_4.

678   All of these segments are

679   connected *explicitly* to

680   FTSeg_1, which is the

681   entire line segment

Figure 5 - FTSeg_2, FTSeg_3, and FTSeg_4 are connected explicitly to FTSeg_1

682   terminating at P1 and P2. The values entered in the important fields of the Connectivity

683   Table are as follows:

Field #2- FTRP-ID	Fields #1, #3, #6, #7	Field #4- FTSeg-ID	Field #5- FTSeg- Offset-%
P3	Other Data	FTSeg_2	0.00%
P3	"	FTSeg_1	42.75%
P4	"	FTSeg_3	100.00%
P4	"	FTSeg_4	0.00%
P4	"	FTSeg_1	72.95%

691   2.4.3.3   Two or more FTSeg are said to be *implicitly* connected when there are two or

692   more records in the Connectivity Table which describe the same FTRP, and all

693   of these records indicate that the FTRP lies on the (multiple) FTSeg at a point

694   other than a terminus of the FTSeg. The implicit connectivity illustrated in

695   Figure 5 is implemented in the Connectivity Table in two records for FTRP_1,

696   each indicating that it is offset a specific percentage of the length of FTSeg_1

697   and FTSeg_2. The Table would contain one record for any additional FTSeg

698   which passed through or which terminated at FTRP_1.

699   2.4.4   Conditions lacking Connectivity

700   2.4.4.1   An FTRP which does not connect

701   multiple FTSeg may be offset

702   along the length of an FTSeg in

703   order to establish the distinction
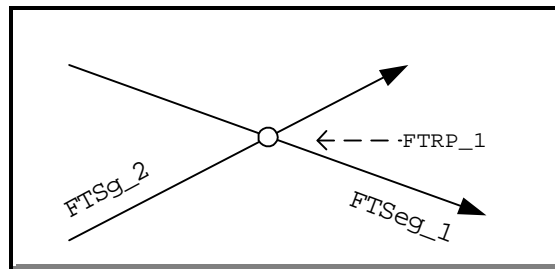
Figure 6 - Implicit connectivity of FTSeg_1 and FTSeg_2

704   among two or more segments which terminate at the same two endpoints. Such

705   an FTRP is recorded as the Intermediate-Point of the FTSeg record to establish

706   uniqueness, and should be recorded in the Connectivity Table.

707   2.4.4.2   An unconnected FTRP may be offset along the length of an FTSeg to mark its

708   intersection with an important but unconnected linear feature (jurisdiction

709   boundary, railroad or water bridge), and should be recorded in the Connectivity

710   Table.

711   2.4.4.3   The topological properties of

712   FTSeg consist exclusively of the connectivity

713   derived from a shared FTRP.

714   Therefore FTSeg_1 and

715   FTSeg_2 may cross without the

Figure 7 - Intersecting but unconnected FTSeg

716   need for an FTRP at the

717   crossover, as in Figure 7. There is no connectivity between the transportation

718   segments illustrated in this figure; no topological connection exists for

719   FTSeg_1 and FTSeg_2 unless an FTRP is defined in order to provide for a

720   topological connection.

721   2.4.4.4   Two unconnected FTRP may

722   share the same horizontal

723   coordinates, though not the same

724   elevation. In such circumstances
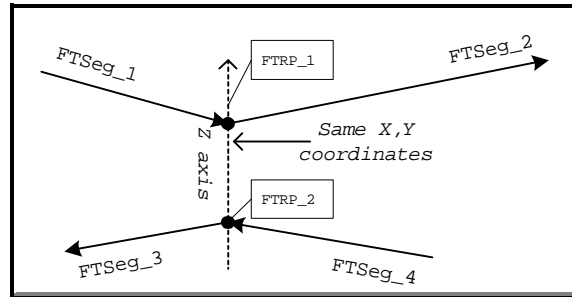
725   there is no implication either that

Figure 8 - Unconnected sets of FTSeg

726   the two FTRP are identical, or that the two sets of FTSeg are connected.

727   Figure 8 shows that FTSeg_1 and FTSeg_2 are connected terminally at

728   FTRP1, and that FTSeg_3 and FTSeg_4 are connected terminally at FTRP2.

729   FTRP1 and FTRP2 share the same (X-Y) coordinates but have different

730   elevations, so there is no connectivity between the two sets of FTSeg.

731   Using terminal, implicit, and explicit connectivity encoded in the Connectivity Table,

732   selected subsets of FTSeg may be combined to create custom networks. The only

733   requirement for the derivation of such networks is that any FTSeg included in the network

734   must connect with another FTSeg that is also part of the network.

735   2.5 Relating Attributes of Transportation Segments to FTRP and FTSeg

736   Organizations that wish to share information about different transportation databases will

737   have an interest in identifying those "real world" feature attributes (e.g. functional class,

738   name or route number, and street address ranges) of value within their applications. The

739   identification of such attributes, definition of their domains or formats is not a part of this

740   Standard. This and other information about these attributes will be defined by national

741   standards and practices, or by the users of the data for a particular geography.

742   Often the values of defined attributes of linear features will not relate to 100% of the

743   length of a particular FTSeg. These attributes -- in addition to attributes pertaining to an

744   FTRP or a complete FTSeg – can be shared by means of an Attribute Table that relates

745   the particular attribute values to one or more FTRP or FTSeg. The Attribute Table

746   supports a "many-to-many" relationship between FTRP and FTSeg objects, and the

747   attributes associated with each, so is in the form of an unordered list:

#	Attribute Table Field-Name	Description & Format/Domain
1	Authority-ID	Permanent and unique identifier of the authority which generates or distributes the attribute. Format specified in Section 2.8
2	FW-Transportation-Segment-ID-or-Reference-Point-ID	Permanent and unique identifier for the FTSeg or FTRP with which an attribute is associated Format specified in Section 2.6
3	Date	Date of creation of the attribute record Format YYYYMMDD

748 (row 1 header), 749 (Authority-ID), 750 (FW-Transportation-Segment), 751 (Date)

752	4	Start-Offset	For FTRP attributes: "000.0000"
			For FTSeg attributes: Percentage offset from the FTSeg From-End-Point at which this attribute value commences
			A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
753	5	End-Offset	For FTRP attributes: "000.0000"
			For FTSeg attributes: Percentage offset from the FTSeg From-End-Point at which this attribute value ends
			A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
754	6	Attribute-Name	Free text: 64 characters or less
755	7	Attribute-Value	Attribute value

756   Values are required for all fields. Descriptions of **Authority-ID, FTSeg-or-FTRP-ID,**

757   **Date,** and **Offset**s can be found in the discussion of the FTSeg Table earlier in section

758   2.3.2.2. **Attribute-Name** and **Attribute-Value** are fields which should contain the name

759   applied by the Authority to a specific attribute, as well as the value of that attribute.

760   Attribute values conveyed in table records apply to the FTRP or FTSeg (or portion

761   thereof) identified in the particular record. Information about different named attributes

762   (e.g., "Route-#" and "Road-Name") must be conveyed in separate records pertaining to

763   each FTRP or FTSeg (or portion thereof). Metadata about each named attribute –

764   including the description, format and domain – should accompany the Attribute Table, and

765   should conform to the FGDC Content Standard for Digital Geospatial Metadata (version

766   2.0).

767   2.6   Unique Identifiers of FTRP and FTSeg

768   Each FTRP and FTSeg has a unique and permanent identification code of fixed length in

769   the following format:

770   **AAAAA.O.XXXXXXXXX**

771   2.6.1   Authority-ID

772   **AAAAA** – Each FTRP and FTSeg identifier includes the unique identifier of an

773   Framework Transportation Data Authority. This code identifies the organization which

774   generated the first database entry, or "originating" record describing the FTRP or FTSeg.

775   An Authority-ID also occurs in a separate data base field in each FTRP and FTSeg record.

776   This field records the identity of an authority which improves database records about

777   FTRP or FTSeg subsequent to the creation of the unique FTRP or FTSeg identifiers.

778   (Specifications for creating identifiers for each authority are the topic of a following

779   section.).

780   2.6.2   Object Type

781   **O** – Each FTRP identifier includes a "P" and each FTSeg includes an "S."

782   2.6.3   Identity-Code

783   **XXXXXXXXX** is a zero-filled, right-justified, alpha-numeric identifier of nine characters

784   in length for each FTRP or FTSeg. Authorities can use different methods for designating

785   unique values for the Identity Code; assignment of sequential integers, or use of segment

786   codes already in use are acceptable methods. Such codes, once assigned, are part of the

787   permanent identifier of each FTRP and FTSeg, and do not change if the pre-existing

788   codes change in a particular user database or application.

789   2.7   Relating Equivalent Representations of FTRP and FTSeg

790   2.7.1   Equivalent FTRP and FTSeg

791   At points of connectivity between differing representations of the traveled way(s) all

792   FTSeg must be capable of connecting to other FTSeg. And wherever authorities maintain

793   databases describing different representations of equivalent features FTRP and FTSeg

794   must be related so they can support exchange of attributes across these databases.

795   2.7.1.1   Many authorities will maintain databases in which two or more traveled ways

796   separated by a physical barrier are represented by two or more sets of line

797   segments, which can be represented as separate segments.

798   2.7.1.2   Other data authorities may maintain databases in which parallel traveled ways

799   separated by a physical barrier are represented by a single set of line segments;

800   e.g. a small-scale representation of an Interstate highway.

801   2.7.1.3   Still other authorities may maintain databases in which the same roadway is

802   represented with "complex" features such as lanes, access roads, and

803   entrance/exit ramps. "Complex" FTRP or FTSeg represent multiple discrete

804   physical points or segments included within the same undivided travelway, over

805   any of which vehicles can pass while remaining within that traveled way.

806   2.7.2   The FTSeg and FTRP Equivalency Table

807   Equivalence among multiple representations of FTRP and FTSeg can be sustained by the

808   creation and maintenance of Equivalency Table data records that establish analogous

809   relationships between two or more FTRP, or between one FTSeg and another FTSeg (or

810   portion thereof.) One FTRP (or FTSeg) may have 0 or 1 or more FTRP (or FTSeg)

811   which are equivalent, but which make up a different representation. Since one FTSeg also

812   may be equivalent to a fraction of another FTSeg, the Table supports "many-to-many"

813   relationships, and is in the form of an unordered list:

#	Equivalency Table Field-Name	Description & Format/Domain
814			
1	Reference-FTRP-ID or Reference-FTSeg-ID	Permanent and unique identifier for the FTRP or FTSeg Format specified in Section 2.6
2	Equivalent_FTRP_ID or Equivalent_FTSeg_ID	Permanent and unique identifier for the FTRP or FTSeg which is equivalent Format specified in Section 2.6
3	Date	Date of creation of the record Format YYYYMMDD
4	Start-Offset *(required if the entity named in Fields 1 & 2 is an FTSeg)*	For FTSeg records only: Percentage offset from the From-End-Point of the FTSeg identified in the Reference-FTSeg-ID at which equivalency commences A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
5	End-Offset *(required if the entity named in Fields 1 & 2 is an FTSeg)*	For FTSeg records only : Percentage offset from the From-End-Point of the FTSeg identified in the Reference-FTSeg-ID at which this equivalency ends A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
6	Status	**P** = Proposed; **A** = Active; **R** = Retired

The numbers 814–820 label the rows in the left margin: 814 (header), 815 (row 1), 816 (row 2), 817 (row 3), 818 (row 4), 819 (row 5), 820 (row 6).

821   The **Reference-FTRP-ID** or **Reference-FTSeg-ID** and **Equivalent_FTRP_ID** or

822   **Equivalent_FTSeg_ID** are the IDs of entities which have been created in the FTSeg

823   Table or the FTRP Table, and which are equivalent (wholly or in part). The **Start-Offset**

824   and **End-Offset** are percentage numbers used to identify the portion of two different

825   FTSeg which are equivalent (wholly or in part). Authorities must indicate equivalency by

826   making entries in this Table whenever they create:

827   2.7.2.1   a new representation of a point or segment which is equivalent to one or more

828   other representations of the same point or segment identified by already-existing

829   FTRP or FTSeg,); or

830   2.7.2.2   a representation of a (new) FTSeg that is equivalent to a fraction of another

831   FTSeg representation.

832   2.7.3   Relating Equivalent FTRP and FTSeg

833   Each FTRP and FTSeg which represents a portion of a transportation network is assigned

834   a unique Identity Code which is a permanent nine-character identifier. Each authority

835   creates or uses an FTRP-ID or FTSeg-ID to identify segments and points in one (or more)

836   specific database(s), and makes entries in the Equivalency Table when these segments and

837   points represent the same physical features represented in other databases using other
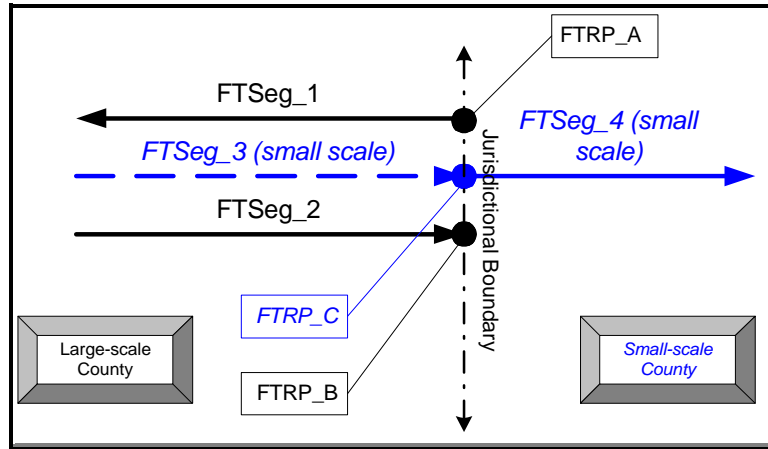
838   FTRP-IDs or FTSeg-IDs.

839   In Figure 9, an authority

840   has created a more-detailed

841   representation of the

842   divided highway to the left

843   of the boundary; segments

844   are identified as `FTSeg_1`

845   and `FTSeg_2`. For

846   another less-detailed

Figure 9 - Equivalency between "Single line" and "Dual line" representations of a Divided Roadway

847   representation of the same segments an authority has used FTSeg-ID numbers `FTSeg_3`,

848   and has connected it to `FTSeg_4`. The authority should make entries in the Equivalency

849   Table to indicate that `FTSeg_1, FTSeg_2`, and `FTSeg_3` are all representations of

850   the same feature(s). (Similar entries should be made to indicate that the three FTRP are

851   equivalent.) Use of the Equivalency Table supports establishment of equivalency between

852   any number of representations of equivalent points (FTRP), and any number of

853   representations of equivalent segments or partial segments (FTSeg) on a "one to many" or

854   "many to one" basis. The entries which should be made in the important fields of the

855   Equivalency Table in order to represent the equivalent entities illustrated in Figure 9 are as

856   follows:

857
858
859

Field #1- Reference-ID	Field #2 - Equiva-lent-ID	Field #4- Start-Offset	Field #5- End--Offset

FTSeg_1	FTSeg_3	0.00%	100.00%
FTSeg_2	FTSeg_3	100.00%	0.00%
FTRP_A	FTRP_C	0.00%	0.00%
FTRP_B	FTRP_C	0.00%	0.00%

864   2.8   Framework Transportation Data Authorities

865   An NSDI Framework Transportation Data Authority may perform some or all of the

866   functions necessary to build and operate the NSDI Framework. These functions are: *Data*

867   *Development, Maintenance, and Integration, Data Access, Data Management,*

868   *Coordination, Executive Guidance, Resource Management*, and *Monitoring and*

869   *Response*. For further information, see the "NSDI Framework Introduction and Guide,"

870   FGDC, 1997, Chapter 4.

871   2.8.1   Definition of an Authority

872   Any organization which takes responsibility for proposing, designating, or working in

873   partnership with other organizations to define FTRP and FTSeg is -- for the purposes of

874   this standard -- operating as an "authority." Organizations which act as authorities:

875   2.8.1.1   create or update transportation databases (or plan to do so), and

876   2.8.1.2   share those databases or related attribute sets with others (or plan to do so), and

877   2.8.1.3   conform database development and maintenance activities to this standard.

878   2.8.2   Unique Identifiers for Authorities

879   Each authority is identified by a permanent, unique, fixed-length code of five characters in

880   the form of **AAAAA**. Organizations which perform authority functions in one state or any

881   part of one state will assume a unique identifier, the first two characters of which consist

882   of the state or territory code specified in FIPS 6-4. The following three characters consist

883   of a unique code for each authority located within the state. The code should be made up

884   of three numeric characters. *EXAMPLE: The Vermont Agency of Transportation could*

885   *assume an Authority-ID of "50001," the Vermont Enhanced-911 Board could assume the*

886   *Authority-ID of "50002," with other state-specific state, regional and local agencies*

887   *assuming other identifiers.*

888   Federal agencies, organizations which produce data for multiple states, and non-domestic

889   authorities can all be accommodated by using the code of "00" in the first two characters.

890   The remaining three characters consist of a code unique to each authority, as described in

891   the previous section. Multi-state authorities which have multiple database maintenance

892   operations or separate geographic units can assume separate Authority-IDs. *EXAMPLE:*

893   *Some federal agencies which are FGDC members perform data development and*

894   *maintenance in facilities in multiple regions of the US. Such regional data maintenance*

895   *facilities may choose to become authorities, and each should use a unique code*

896   *beginning with "00."*

897   2.8.3   Descriptive Attributes for each Authority

898   Information about each authority is maintained in an NSDI Framework Authority Index;

899   (See Part 3 - Implementation Procedures). The information content relating to each

900   authority is based on the "Contact-Information" content specified within the FGDC

901   "Content Standard for Digital Geospatial Metadata." It includes the following

902   information:

#	Authority Field-Name	Description & Format/Domain
1	**Authority-ID**	Permanent and unique identifier of the organization. Five character numeric code: see Section 2.8.1 and 2.8.2
2	Date	Date of creation of the record Format YYYYMMDD
3	Authority-Name	Name of the organization acting as an authority Free text: 255 characters or less
4	Contact-Person-Primary	Name of a contact person Free text: 255 characters or less
5	Contact-Voice-Telephone	Voice telephone number of Contact-Person-Primary Free text: 20 characters

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904
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909	6	Contact-Facsimile-Telephone *(optional)*	Fax telephone number of Contact-Person-Primary
			Free text: 20 characters
910	7	Contact-Electronic-Mail - Address *(optional)*	E-mail address of Contact-Person-Primary
			Free text: 64 characters or less
911	8	Contact-URL *(optional)*	Universal Resource Locator for Internet access to the Authority
			Free text: 64 characters or less
912	9	Contact-Instructions	Instructions for contacting the Authority
			Free text: 255 characters or less
913	10	Authority-Address	Mail delivery address of the Authority
			Free text: 255 characters or less
914	11	Authority-City	Mail delivery city of the Authority
			Free text: 255 characters or less
915	12	Authority-State-or-Province	Mail delivery state (US) or province (non-US) of the Authority
			Free text: 64 characters or less
916	13	Authority-Postal-Code	Mail delivery ZIP (US) or postal code of the Authority
			Free text: 20 characters or less
917	14	Authority-Country	Mail delivery Country of the Authority
			Free text: 64 characters or less
918	15	Authority-Index-Access-Information	Information informing potential users of the Authority's data how to obtain access to or a copy of the index containing the relevant FTRP and FTSeg information. Link(s) to the standardized metadata describing the database(s) should be included.
			Free text: 255 characters or less

919	16	Authority-Information *(optional)*	Additional information about the geographic area, types of transportation activities, or data maintenance operations in which the Authority is engaged
			Free text: 255 characters or less
920	17	Status	**P** = Proposed; **A** = Active; **R** = Retired

921   **Appendix A – Terminology**

922   (Informative)

923   This appendix contains terms used throughout this document, with reference to broader

924   technical glossaries developed by other organizations.

925   Definitions for the terms and concepts presented in this section have been extracted from a

926   variety of sources. Where appropriate, language has been retained from existing

927   definitions, including from the Spatial Data Transfer Standard (SDTS), by the FGDC

928   Ground Transportation Subcommittee, the NCHRP Report 359, and concept and

929   workshop papers recently authored by Butler, Dueker, Fletcher, Vonderohe, et al. When

930   utilized, specific references to these sources appear in parentheses following the

931   definitions.

932   **Arc**. A locus of points that forms a curve that is defined by a mathematical expression

933   (SDTS).

934   **Chain**. A directed non-branching sequence of nonintersecting line segments and (or) arcs

935   bounded by nodes, not necessarily distinct, at each end (SDTS).

936   **Framework Transportation Reference Point (FTRP)**. The specified location of a

937   endpoint of a Framework Transportation Segment (FTSeg), or a reference point offset

938   along the length of the FTSeg, on a physical transportation system.

939   **Framework Transportation Segment (FTSeg)**. A specified directed path between two

940   Framework Transportation Segment Reference Points along a physical transportation

941   system that identifies a unique segment of that physical system.

942   **Line**. A generic term for a linear object. Lines can be defined variously as "line segment,"

943   "string," "arc," or "chain." Lines have shape and position.

944   **Line segment**. A direct line between two points (SDTS).

945   **Linear datum**. The collection of objects which serve as the basis for locating the linear

946   referencing system in the real world. The datum relates the data base representation to the

947   real world and provides the domain for transformations among linear referencing systems

948   and among geographic representations. The datum consists of a connected set of anchor

949   sections that have anchor points at their junctions and termini (Fletcher). A linear datum is

950   not based upon a network with GIS geometry, but instead is properly considered to be an

951   abstract representation of objects (lines, nodes) that describes how the objects are related.

952   **Linear Referencing Method** (LRM). A mechanism for finding and stating the location of

953   an unknown point along a network by referencing it to a known point (Vonderohe).

954   Common methods include milepost, link-node, route-segment-offset, and address.

955   **Linear Referencing System** (LRS). The procedures that relate all location referencing

956   methods to each other, including office and field techniques for storing, maintaining, and

957   retrieving location information (O'Neill).

958   **Link**. A topological connection between two ordered nodes (Vonderohe, SDTS). Links

959   do not necessarily have shape or position.

960   **Link-Node**. A location referencing method based upon a unique numbering system

961   describing links (or arcs) and nodes; it does not inherently contain measurement data.

962   **Location.** The name given to a specific point on a highway for which an identification of

963   its linear position with respect to a known point is desired. (TRB, 1974)

964   **Locational Referencing Method (Highway)**. The technique used to identify a specific

965   point (location) or segment of a highway, either in the field or in the office. (TRB, 1974)

966   **Locational Referencing System (Highway)**. The total set of procedures for determining

967   and retaining a record of specific points along a highway. The system includes the

968   location reference method(s), together with the procedures for storing, maintaining, and

969   retrieving location information about the points and segments on the highways. (TRB,

970   1974)

971   **Milepost/Milepoint/Reference Post**. A commonly used location referencing method.

972   Location of features is specified as a measured distance or offset from a known point such

973   as an intersection. In the field, reference posts may be used as the primary known point.

974   **Network**. A graph without two-dimensional objects or chains. An aggregation of nodes

975   and links representing a topological object (SDTS, Vonderohe). A network implies that

976   there is a graphic connectivity, or topology, among elements.

977   **Node**. A zero-dimensional object that is a topological junction of two or more links, or an

978   end point of a link or chain (Vonderohe, SDTS).

979   **Point.** A zero-dimensional object that specifies geometric location. A pair (e.g., "x,y") or

980   triplet (e.g., "x,y,z") of coordinates specifies the location (SDTS).

981   **String**. A connected non-branching sequence of line segments specified as the ordered

982   sequence of points between those line segments (SDTS).

983   **Topology**. A branch of mathematics concerned with those properties of geometry that are

984   independent of a distance metric and are unchanged by any continuous deformation.

985   Topology, as used in cartography, concerns those characteristics of geometric objects that

986   do not depend on measurement in a coordinate system. (Chrisman)

987   **Traversal**. An ordered and directed, but not necessarily connected, set of whole links

988   (Vonderohe).

FGDC-STD-999.1-2000

989   **Appendix B – Bibliographic References**

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1044   **Appendix C – Implementation Procedures**

1045   (Informative)

1046   This section includes guidelines for placement of Framework Road Segments (FTSeg) and

1047   Framework Road Segment Reference Points (FTRP). It also describes recommended

1048   procedures for implementing this standard, conventions for cartographic display of FTRP

1049   and FTSeg, and conformance testing.

1050   3   Implementation Procedures

1051   The NSDI Framework Transportation Identification Standard imposes only one constraint

1052   with respect to how a physical road is partitioned into FTSeg: segments must not span

1053   state borders. This section therefore provides a set of guidelines for placing FTRP and

1054   creating FTSeg that are expected to meet the needs of a great many – but not all – of

1055   those organizations that wish to participate in sharing road information. These guidelines

1056   are intended to be compatible with the practices of organizations that support network

1057   applications and require connectivity of the links and nodes which correspond to the

1058   FTSeg and FTRP defined in this standard.

1059   The procedures recommended in these guidelines are consistent with the level of detail

1060   found in maps at scales ranging from 1:12,000 to 1:24,000. Many transportation

1061   databases are being created at these scales by digitizing from USGS quadrangles or from

1062   standard Digital Orthophoto Quarter Quadrangles (DOQQs). This section offers

1063   procedures and rules of good practice intended for use at this scale: other users

1064   developing databases at smaller or larger scales may need to consider departures from

1065   these procedures. These procedures are specifically not applicable to users whose

1066   applications are based on CAD-scale engineering databases that graphically depict

1067   roadway widths, curbs, right-of-ways, etc.

1068   FTSeg should be created to represent those segments of roads about which attributes

1069   (including cartographic shape) are to be shared among organizations. Segmentation of

1070   roads into links which are specific to particular network applications (e.g., driveway-to-

1071   driveway road segments for E-911 dispatch, shopping center parking lots for transit buses,

1072   or back alleys for trash collection) do not require FTSeg unless they have associated with

1073   them information useful to other users or applications.

1074   Road data authorities should coordinate the development of a road data base with all

1075   relevant stakeholders, particularly with respect to which roads should be included in a

1076   local implementation. The decision of which roads to include should reflect a reasonable

1077   compromise between an economical number of FTRP and FTSeg, and common network

1078   application needs of the stakeholders. *Example: A local E-911 agency may wish to*

1079   *incorporate intersections of local roads with private driveways. However, such a data*

1080   *structure would proliferate the number of FTSeg in the road database. Unless other*

1081   *cooperating road data authorities agree that this structure is useful, they should place*

1082   *FTRP only at intersections of public roads; the E-911 agency can create a supplemental*

1083   *road database using explicit connectivity to join driveways to local roads.*

1084   3.1 Cartographic Representation of FTRP and FTSeg

1085   3.1.1   Display of County and State Density

1086   The state to which each FTSeg record pertains is encoded within the unique identifier, as

1087   is the state in which an Authority operates (with some exceptions.) This information, plus

1088   the coordinates of FTRP, can be used to display general location and density of FTRP and

1089   FTSeg records.

1090   3.1.2   Display of FTRP and FTSeg

1091   3.1.2.1   FTSeg should be depicted either

1092   by straight lines connecting two

1093   FTRP or by curved lines (if two
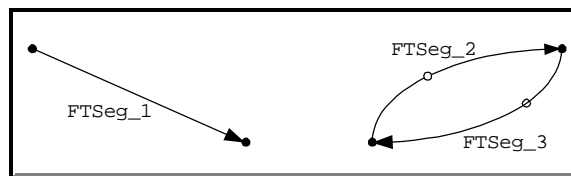

Figure 10 – Cartographic representation of FTSeg

1094   or more FTSeg terminate at the

1095   same two FTRP.) Each FTSeg should be displayed as a line terminating in a

1096   single "arrow-head" at the "To-FTRP" terminus. Various line symbols and

1097   widths may be used. More realistic cartographic representation of FTSeg

1098   requires that they be linked to table(s) of attributes which include the

1099   coordinates of shape points.

1100   3.1.2.2   Coordinate values (horizontal) and related accuracy statement fields are required

1101   within each FTRP record. Availability of this information will allow the

1102   cartographic display of point locations along with information about the known

1103   accuracy of each. FTRP should be symbolized as one of three representations

1104   of circles.

1105   3.1.2.2.1 FTRP which terminate one or more FTSeg, and

1106   through which no FTSeg pass without

1107   terminating, should be represented by a filled

1108   circle. Such FTRP indicate terminal

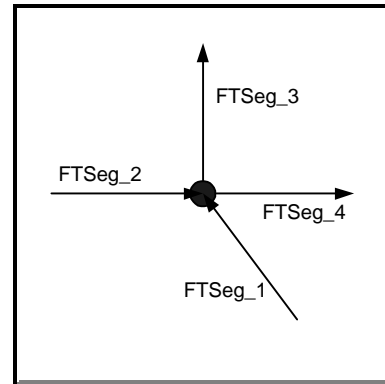1109   connectivity.

Figure 11 - Cartographic representation of terminal connectivity at an FTRP

1110   3.1.2.2.2 FTRP which do not lie at the terminus of any

1111   FTSeg should be represented by an open circle;

1112   the lines representing FTSeg which pass

1113   through the FTRP should not be visible within

1114   the unfilled (opaque) center of the circle. Such

1115   FTRP might not indicate any FTSeg

1116   connectivity; e.g., they are used to indicate a

1117   unique Intermediate Point on an FTSeg.

1118   Alternatively, such FTRP might indicate

Figure 12 - Cartographic representation of no connectivity at an FTRP

1119   implicit connectivity; e.g., two FTSeg cross at -- but do not terminate at -- an

1120   FTRP.

1121   3.1.2.2.3 FTRP which terminate one or more FTSeg, and

1122   through which one or more FTSeg pass

1123   without terminating, should be represented by

1124   an unfilled circle; the lines representing FTSeg

1125   which pass through or terminate at the FTRP

1126   should be visible within the unfilled

1127   (transparent) center of the circle.
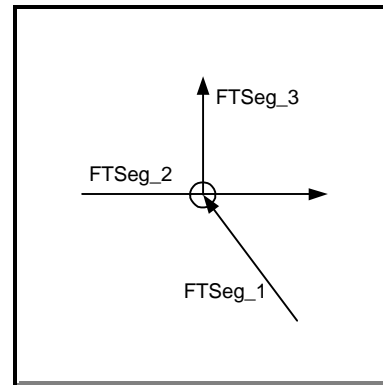

Figure 13 - Cartographic representation of mixed connectivity at an FTRP

1128   3.1.3   Relationship to Other Cartographic Elements

1129   FTRP and FTSeg identifiers will be encoded as attributes associated with lines and

1130   intersections within geographic information systems, and associated with links and nodes

1131   in network representations. Cartographic representations which utilize FTRP and FTSeg

1132   should be carefully symbolized, labeled and/or annotated so that users do not impute to

1133   the FTRP and FTSeg position or precision which is not warranted, or confuse them with

1134   links and nodes. FTSeg have no shape points or inherent geometry, and need not have a

1135   measured length. Users will associate them with arcs and chains contained within their

1136   datasets, and display them as such. Such display of FTSeg will be necessary during the

1137   process of their initial definition and subsequent updates, and will be helpful to many

1138   users.

1139   3.2   Establishing Framework Road Segment Reference Points (FTRP)

1140   3.2.1   At Jurisdictional Boundaries

1141   FTRP should be placed wherever a road crosses a jurisdictional boundary between two

1142   road data authorities. The road data authorities on either side of the jurisdictional

1143   boundary should coordinate the identification and placement of the FTRP so that one

1144   common FTRP is used to identify the crossing point. *Example: Two neighboring states*

1145   *should coordinate identification of FTRP at their common boundary with each other and*

1146   *with contiguous counties and/or other jurisdictions (where pertinent) who share the same*

1147   *boundary line(s).*

1148   3.2.1.1   State and International Borders

1149   FTRP must be placed wherever a road crosses a state border, regardless of whether or not

1150   there is a designated road data authority in the adjoining state or country. Such FTRP

1151   should terminate FTSeg representing any road which intersects the border.

1152   3.2.1.2   County Boundaries

1153   Authorities should consider placing an FTRP wherever a road crosses the boundary

1154   between two counties within a state. Even in those cases where the delineation of a

1155   county boundary is not easily located in the field, placement of an FTRP could facilitate

1156   coordination with authorities and road data users on either side of the boundary.

1157   3.2.2   Simple Road Intersections

1158   An FTRP should be placed wherever two roads of similar

1159   functional class or importance cross one another at grade.

1160   Roads segments which share a common FTRP are

1161   connected terminally or explicitly; therefore no additional

1162   information is required in order to establish connectivity

1163   in any application network built from the road data.

1164   Road data authorities should identify those roads for

1165   which they want to ensure connectivity in all network

1166   applications and place FTRP at each intersection.
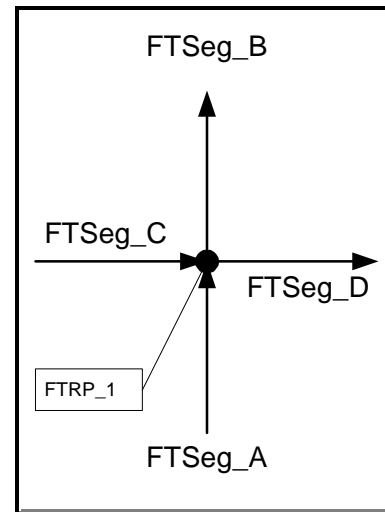
Figure 14 - Simple Road Intersection

1167   *Example: A state DOT may wish initially to construct a statewide road base map,*

1168   *consisting only of state highways, U.S. routes and Interstate highways. FTRP would be*

1169   *placed only at the intersections of these roads. Intersections with county and local roads*

1170   *could be accommodated at some future time through explicit connectivity to FTSeg on*

1171   *the statewide road base map.*

1172   A single FTRP can be created to represent the intersection of two or more roads; it can be

1173   used to terminate all segments of intersecting roads (illustrated in Figure 14 as terminal

1174   connectivity of segments FTSeg_A, B, C, and D.)

1175   In addition, a single FTRP can be created to represent an intersection of two or more

1176   roads where not all segments of intersecting roads terminate (illustrated in Figure 15 as

1177   explicit connectivity of segments FTSeg_E, F, and

1178   G.) A cartographic convention used in this figure

1179   places an arrow-head at FTRP_2, where the

1180   FTRP breaks the "east-west" road into two

1181   segments[6]. FTSeg_G passes through the same

1182   point unbroken, as is indicated by the lack of an

1183   arrow-head at FTRP_2. FTRP_2 provides

1184   terminal connectivity between the two segments

Figure 15 Simple Road Intersection

1185   for which it serves as a terminus. If it also serves to connect one or more terminated

1186   segments to an unbroken segment, then the FTRP data record also provides for explicit

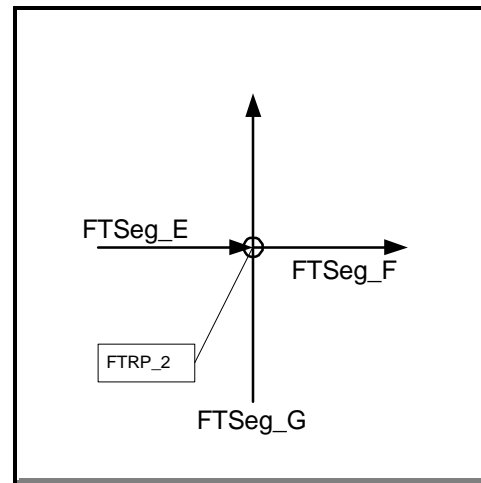1187   connectivity to the unbroken other segment – illustrated as FTSeg_G.

1188   3.2.3   Offset Intersections

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[6]See Implementation Procedures – Section 1.1 for recommenced cartographic conventions.

1189   Occasionally, one road may intersect another at two distinct intersections offset by a short

1190   distance. In order to avoid creating a very short FTSeg, road data authorities should use

1191   an FTRP to represent explicit connectivity at only one of the intersections. Depending on

1192   the level of spatial resolution represented in the road database, the second (offset)

1193   intersection may be joined using explicit connectivity, or the offset distance may be

1194   ignored and treated as a conventional at-grade intersection.

1195   3.2.4   Overpasses and Underpasses

1196   FTRP may be placed at grade-separated crossings such as overpasses or underpasses in

1197   order to meet several needs. First, if placed at such a crossing the FTRP could represent

1198   the terminal connectivity of two segments which terminate on the upper grade or the

1199   lower grade. Similarly, if segments terminate on both roads, two separate FTRP should

1200   be used to represent connectivity at the upper and lower termini. Finally, an FTRP can be

1201   placed at such an intersection and not serve as a terminal point of any segment; i.e., it

1202   could serve only as an "intermediate-point" of one of the segments. In summary,

1203   placement of an FTRP at such a location requires users to provide additional information

1204   in any network applications, so that users do not make unsupported assumptions about

1205   implicit connectivity.

1206   3.2.5   Grade-Separated Interchanges

1207   Grade-separated interchanges consist of one or more overpasses, and entrance and exit

1208   ramps to connect the otherwise non-intersecting main roads. In general, an FTRP does

1209   not need to be placed at the location of the overpassing roads if network connectivity can

1210   be established using the ramps. However, road data authorities may wish to place FTRP

1211   at interchanges in order to create manageable length road segments. *Example: On*

1212   *limited-access highways a state DOT may choose to establish FTSeg that go from*

1213   *interchange to interchange.*

1214   If an FTRP is placed at a grade-separated interchange, it should only connect one of the

1215   two crossing roads, not both. In other words, the FTRP should serve as the end point for

1216   only two FTSeg, either the over passing road or the under passing road, but not both. If

1217   the transportation data authority chooses to segment both roads at the interchange, two

1218   unique FTRP should be created, one connecting the over passing road, and one

1219   connecting the under passing road. These FTRP may either be assigned the same X-Y

1220   coordinate values, or may be offset from one another.

1221   3.2.5.1   Entrance and Exit Ramps

1222   An FTRP should not terminate a segment of a road at every gore point (i.e., intersection)

1223   where the road is joined by entrance or exit ramps. To do so would divide the road into a

1224   large number of very short FTSeg in the vicinity of the interchange. Entrance and exit

1225   ramps are better handled using explicit connectivity to join the end point of the ramp to

1226   the main road at some specified offset distance along a segment of the road.

1227   3.3   Establishing Framework transportation Segments (FTSeg)

1228   A single FTSeg represents an unambiguously defined path along a physical transportation

1229   network between two FTRP. In most instances, FTRP can and should be selected in such

1230   a way that there is only one path between them along a transportation network In cases

1231   where two or more uninterrupted paths exist between the same two FTRP, the fields for

1232   Intermediate-Point and Path-Description in the FTSeg record must be used to differentiate

1233   among the paths. Transportation data authorities with overlapping responsibilities for a

1234   geographic area should coordinate the identification of FTSeg. *Example: A state DOT*

1235   *and a county road authority are both responsible for building a road framework data*

1236   *base for the county. The technical staff for each agency should agree on which agency*

1237   *has responsibility for identifying FTSeg of which roads (e.g., the state DOT authority*

1238   *designates FTSeg for all Federal and state sign routes, while the county authority*

1239   *designates FTSeg for all county routes and local roads).*

1240   3.3.1   Segment Length

1241 The appropriate FTSeg length represents a tradeoff between maintaining information on a

1242 large number of short segments, and potential errors introduced by measurements over a

1243 long linear segment. This standard prohibits segments which span boundary lines of

1244 states, territories, or equivalent jurisdictions. Transportation data authorities within a

1245 particular geography will need to assess whether more restrictive guidelines regarding

1246 FTSeg length are needed to support common applications among various transportation

1247 database users within that geography.

1248 3.3.1.1   Roads that Cross Jurisdictional Boundaries

1249 Roads that cross state and county jurisdictional lines should be represented by FTSeg that

1250 terminate at the boundaries. Consequently, no FTSeg should be longer than the driving

1251 distance across a state; in all but the most rural areas, authorities should consider

1252 terminating FTSeg at county boundaries.

1253 3.3.1.2   Roads that Coincide with Jurisdictional Boundaries

1254 Roads which run along a jurisdictional boundary should be represented by FTSeg whose

1255 length does not exceed the line dividing the jurisdictions. When a road runs along a

1256 jurisdictional boundary for a portion of the boundary length, an FTSeg should be

1257 terminated where it leaves the boundary line, and a new FTSeg should be initiated –

1258   except in locations where local authorities determine that the departure from the boundary

1259   line is insignificant. Part III-D of this standard provides an example.

1260   3.3.2   Road Types

1261   The decision to represent a particular road by a single FTSeg or two (or more) parallel

1262   FTSeg should be based on scale, accuracy, cartographic and network application

1263   requirements. In general, network applications are facilitated where FTSeg and FTRP can

1264   be directly replaced by network links and nodes. These guidelines are aimed at minimizing

1265   additional work beyond establishing explicit connections for FTSeg to create a flowable

1266   transportation network.

1267   3.3.2.1   Roads with no Access Restrictions or Medians

1268   One-way and two-way roads with no significant access restrictions or physical median

1269   separating directional roadways should be represented by a single FTSeg. Most local

1270   streets, connectors, and minor arterials fall into this category.

1271   3.3.2.2   Roads with Center Medians but no Access Restrictions

1272   Some major urban and rural arterials have a center median which divides the travel lanes in

1273   each direction (e.g., Commonwealth Avenue in Boston). However, intersecting streets

1274   can access either direction of travel lanes via short transportation segments crossing the

1275   median at each intersection. These roads may be represented either by a single FTSeg

1276   which ignores the center median, or by two parallel FTSeg depicting directional roadways

1277   on either side of the median. If parallel FTSeg are used, intersecting FTSeg should be

1278   terminated at only one of the two parallel FTSeg, not both.

1279   3.3.2.3   Limited-Access Divided Highways

1280   Most Interstate Highways and major, high speed expressways can only be entered or

1281   exited via specifically designated ramps. These roads almost always have some median

1282   strip or other physical barrier that prohibits vehicles from reversing direction without first

1283   exiting the highway at a designated ramp. These roads should always be represented by

1284   two FTSeg regardless of the actual physical separation between the lanes (e.g., even roads

1285   which are separated by a concrete "Jersey Barrier" should represented by two FTSeg if

1286   each direction is served by its own entrance and exit ramps.)

1287   3.3.2.4   Physically Separated, Limited-Access Parallel Lanes

1288   Some high volume roads, particularly in urban areas, may designate certain lanes for high

1289   occupancy vehicles (HOV) or auto-only, and physically separate these lanes from the main

1290   travel lanes (e.g., I-395 in northern Virginia, or the New Jersey Turnpike outside New

1291   York City). If these physically separated lanes are served by their own entrance and exit

1292   ramps, they should be represented by their own FTSeg. Furthermore, if the priority lanes

1293   are also separated directionally, each direction should be represented by its own FTSeg.

1294   *Example: The northern end of the New Jersey Turnpike includes physically separated*

1295   *auto-only lanes, running parallel to the main traffic lanes in both directions. Both the*

1296   *main lanes and the auto-only lanes have their own entrance and exit ramps. This facility*

1297   *should be represented by four parallel FTSeg – one for each direction of the main lanes*

1298   *and one for each direction of the auto-only lanes.*

1299   3.3.2.5   Entrance and Exit Ramps

1300   Entrance and exit ramps are one-way or two-way roads that provide general vehicle

1301   access to limited-access highways. Each entrance or exit ramp should be represented by

1302   an FTSeg. FTRP which terminate entrance or exit ramps should use explicit connectivity

1303   to join with the main road which the ramp accesses.

1304   3.3.2.6   Frontage Roads

1305   A frontage or access road is a one- or two way, unlimited-access surface street that

1306   parallels but is physically separated from a more limited-access major arterial. Its main

1307   purpose is to provide access to establishments along the major arterial corridor while

1308   preventing access traffic from disrupting the flow of through traffic on the major arterial.

1309   Access from the frontage road to the major arterial is typically limited to intersections of

1310   cross-streets and/or specifically designated "gaps" in the median or physical barrier.

1311   Frontage roads should be represented by their own FTSeg. Entrance "gaps" between the

1312   frontage road and the main arterial should be treated similar to an entrance or exit ramp.

1313   3.3.2.7   "Stacked" Highways

1314   A stacked highway occurs when one road or directional roadway is built above another

1315   roadway. Although the two roads are separated vertically, when displayed on a two-

1316   dimensional surface (e.g., map or computer monitor) they appear as a single line. Each

1317   road or directional roadway should always be represented by its own FTSeg, regardless of

1318   how they might be displayed.

1319   3.3.3   Complex Intersections

1320   The preceding guidelines provide rules for placing FTRP and using FTSeg to represent

1321   various types of transportation features in a generally consistent way and without creating

1322   short, difficult to locate FTSeg. The following examples illustrate some typical

1323   combinations of roads and intersections and how they might be represented using FTRP,

1324   FTSeg, and explicit connectivity relationships.

1325   3.3.3.1   Full Interchange, Two Limited-Access Divided Highways

1326   The classic "cloverleaf" interchange and its assorted variations of ramps provides network

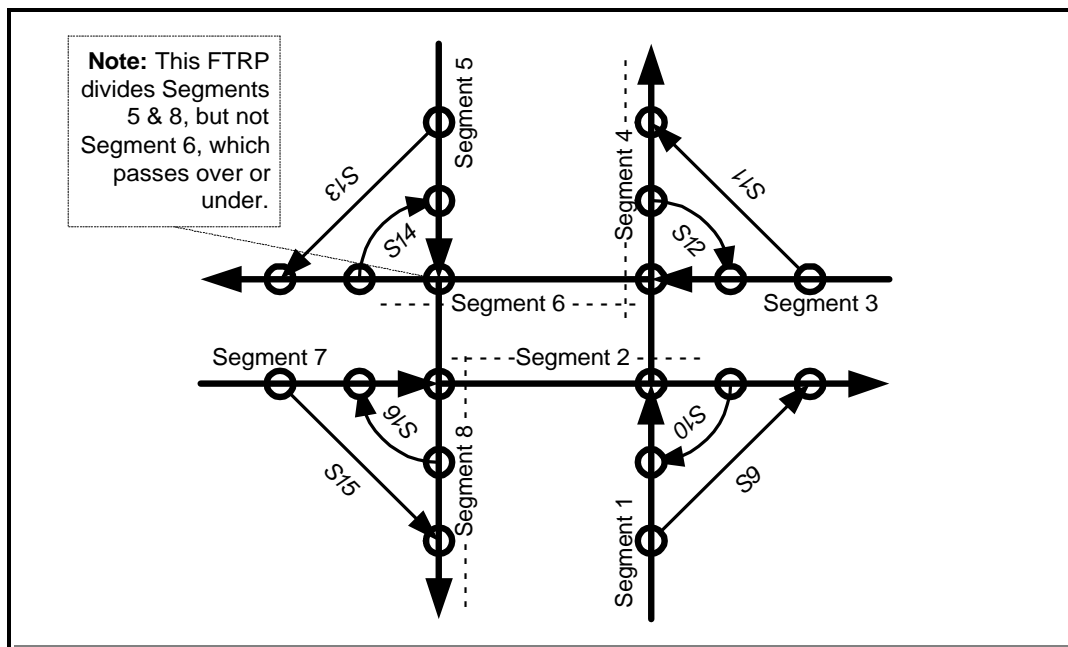1327   connections between two crossing, limited-access divided highways such that there exists

Figure 16 Full Interchange, Two Limited-Access Divided Highways

1328   a valid network connection from any directional roadway to any other roadway. Each

1329   directional roadway should be split only once within the interchange. This can be done by

1330   splitting each incoming directional roadway where it first crosses (either as an overpass or

1331   underpass) a directional roadway of the other highway. Only the incoming FTSeg is split;

1332   the FTRP does not split the crossing directional roadway at this point; the "Note" in

1333   Figure 16 highlights this. The resulting configuration consists of four FTRP, one at each

1334   of the four corners of the intersecting directional roadways. However, each of these

1335   FTRP connects only two of the four apparently intersecting lines. Ramps are added to the

1336   interchange using explicit connectivity to join each endpoint of the ramp to one of the

1337   directional roadways of the crossing highways. The resulting interchange consists of eight

1338   FTSeg for the main highways (each of the four directional roadways is split into two

1339   FTSeg), and up to eight FTSeg for the interchange ramps.

1340   3.3.3.2   "Diamond" Interchange

1341   The classic "diamond"

1342   interchange provides a

1343   network connection

1344   between a limited-access

1345   divided highway and a two-

1346   way surface roadway. On

1347   the divided highway, each

1348   directional roadway should
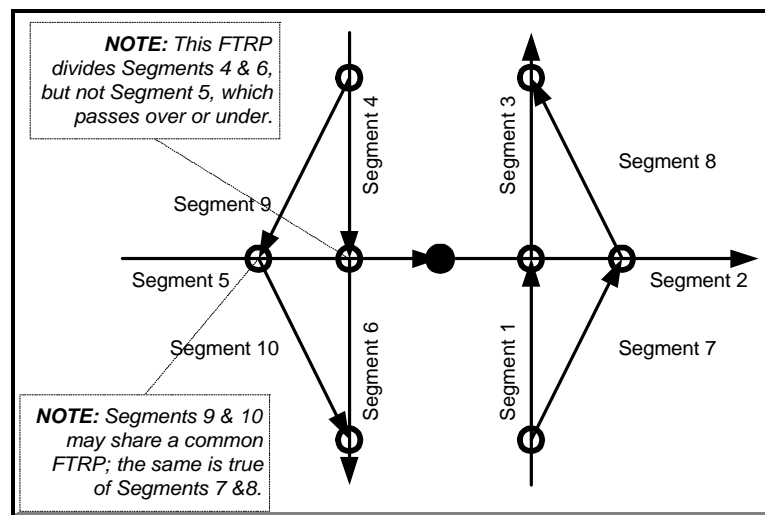
Figure 17 - "Diamond" Interchange

1349   be split where it crosses (either as an overpass or underpass) the two-way street. As with

1350   the full cloverleaf interchange, the FTRP on the directional roadway does not split the

1351   crossing two-way street. The two-way street should be split either by a second FTRP

1352   assigned the same X-Y coordinate values as one of the two FTRP of the directional

1353   roadways, or by an FTRP located "between" the two directional roadways, as illustrated

1354   above. Ramps are added to the interchange using explicit connectivity to join one

1355   endpoint of the ramp to one of the directional roadways of the divided highway and the

1356   other endpoint to a location on the two-way roadway. The resulting interchange consists

1357   of six FTSeg for the crossing roads, and four FTSeg for the interchange ramps.

1358   3.3.3.3   Intersection: Two-Way Surface Street with a Center Median Surface Street

1359   This intersection looks

1360   similar to the "diamond"

1361   interchange, except that

1362   there are no overpassing

1363   roads: the two-way

1364   crossing street actually

1365   intersects each directional

1366   roadway. In order to avoid

1367   creating a very short

1368   FTSeg representing the

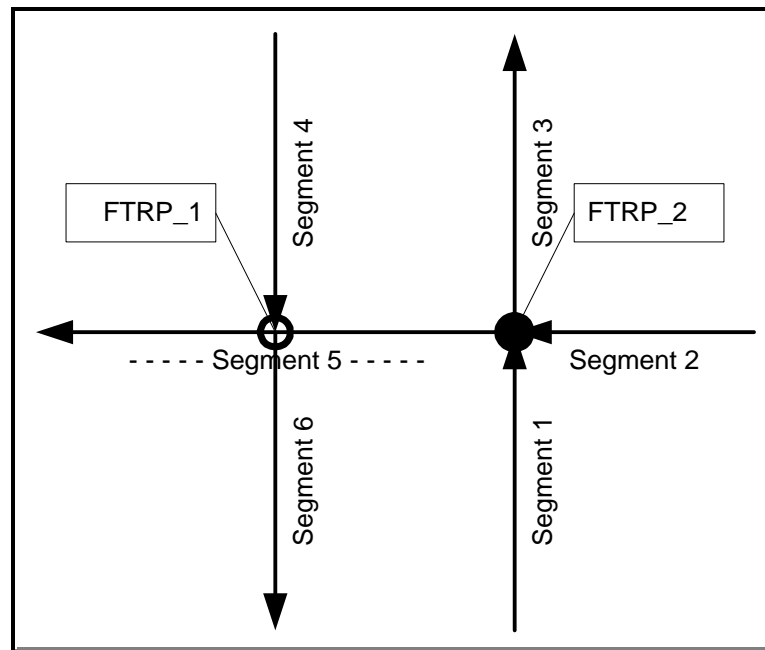**Figure 18** - Intersection: Two-Way Surface Street with a Center Median Surface Street

1369   road surface crossing the

1370   median area, a single FTRP should be placed at one of the two intersections that splits

1371   both the crossing two-way roadway and one of the two directional roadways. This is

1372   labeled as "FTRP-2" in Figure 18. The other directional roadway should be split with an

1373   FTRP -- labeled as "FTRP-1" -- that indicates explicit connectivity to the FTSeg that

1374   represents the crossing two-way road. The resulting intersection consists of six FTSeg

1375   and two FTRP.

1376   3.3.3.4   Traffic Circle

1377   A traffic circle consists of a

1378   circular loop road that is

1379   intersected by several other

1380   roads which radiate

1381   outward from the circle.

1382   The traffic circle should be

1383   represented either as a

1384   single FTSeg that begins
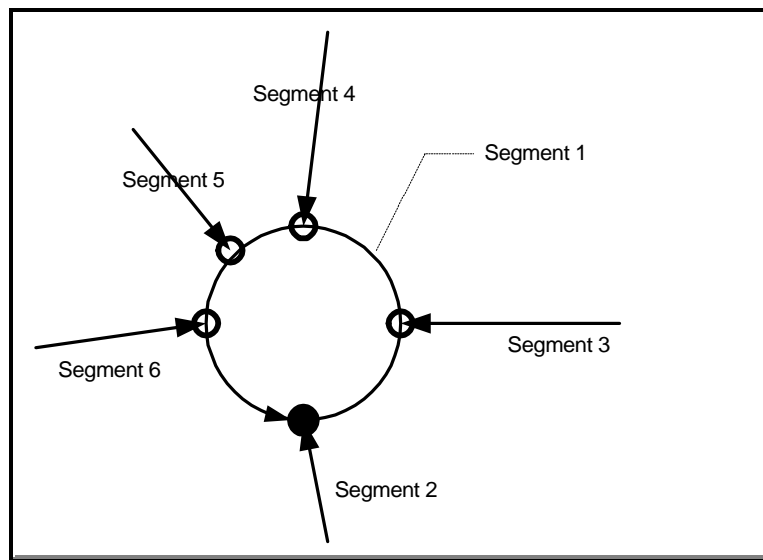
Figure 19 - Traffic Circle

1385   and ends at the same FTRP

1386   (illustrated in Figure 19), or by two FTSeg that each represent some portion of the circle.

1387   The FTRP marking the intersection of each radiating road should be connected to the

1388   traffic circle FTSeg using explicit connectivity to avoid creating short FTSeg between

1389   each radiating road. The path description for the FTSeg representing the traffic circle

1390   should include a direction (either clockwise or counterclockwise) to indicate the order in

1391   which the radiating roads intersect. One of the radiating roads may share the same FTRP

1392   as the traffic circle FTSeg.

1393   3.4   Creating New or Updated FTSeg and FTRP

1394   Multiple FTRP and FTSeg records can exist for any point or segment, because their multi-

1395   part key includes "Authority-ID" and "Date". *"Creating"* FTRP and FTSeg refers to

1396   generating a record keyed with a new and unique FTRP-ID or FTSeg-ID. *"Updating"*

1397   FTRP and FTSeg refers to creating a new database record for a previously-identified

1398   FTSeg or FTRP.   Each "update" record will utilize an already-defined FTRP-ID or

1399   FTSeg-ID, and use a new and unique combination of "Authority-ID" and "Date"

1400   information.

1401   In the normal course of events authorities will update records to reflect improvements in

1402   description or measurement for the same point or segment – even if there is no change in

1403   the "real world" features represented by the FTRP or FTSeg. Older database records are

1404   retained in the index along with the database records which reflect "updates" to non-key

1405   information fields.

1406   3.4.1   Road reconstruction

1407   New FTRP and/or FTSeg records must be created when FTRP are relocated and FTSeg

1408   are re-defined during the (re-)construction of roads or changes in intersection alignment.

1409   This requires retirement of old FTRP and associated FTSeg, and creation of updated

1410   FTRP and FTSeg, as described below. The unique identifier for FTRP and/or FTSeg

1411   records which are retired as a result of (re)construction may be encoded within other

1412   records to which the retired objects are topologically connected. Affected records may

1413   occur in FTRP and FTSeg tables, as well as the Connectivity and Equivalency tables.

1414   Therefore the references in these other records must be updated with the identities of the

1415   objects which have replaced the retired objects, or the records must be retired.

1416   3.4.2   Re-measuring

1417   FTRP and/or FTSeg records should be updated when more accurate measurement of

1418   coordinates/lengths are obtained. This entails creating new records with a unique key

1419   made up of the FTSeg-ID and/or FTRP-ID, the Authority-ID, and the Date, updating the

1420   information in other fields (as appropriate), and carrying forward information from fields

1421   which are not updated.

1422   3.5   Retiring FTSeg and FTRP

1423   3.5.1   Road reconstruction

1424   As stated above, new FTRP and FTSeg should be created during the construction or

1425   reconstruction of roads; e.g., addition of ramps, or changes in intersection alignment.

1426   Those FTRP and FTSeg used exclusively to designate the (old) feature which has been

1427   reconstructed should be retired by changing the "Status" of all records which identify the

1428   (old) feature from "A" (active) to "R" (retired).

1429   3.5.2   FTRP Duplication

1430   Instances can occur in which two authorities create unique FTRP IDs which identify the

1431   same "real world" feature.

1432   3.5.2.1   Before identifying new FTRP each authority should evaluate existing FTRP

1433   records maintained in the distributed index, and should coordinate with other

1434   authorities concerned about the same or contiguous geography, in order to

1435   prevent such duplication. Analysis of the"AAAAA" substrings and the

1436   coordinates of existing FTRP identifiers will in most cases allow an authority to

1437   avoid duplication.

1438   3.5.2.2   When authorities verify that duplicate FTRP-IDs exist for the same feature, they

1439   should retain the unique ID which has the earliest date of assignment. All FTRP

1440   and FTSeg records which contain a duplicate ID should be retired by changing

1441   their "Status" to "R" (retired). Any useful information which is contained

1442   within these (retired) records should be copied into active records that contain

1443   the ID which has been retained, and that are identified uniquely as to

1444   "Authority-ID" and "Date". *Example: Two neighboring jurisdictions use and*

1445   *update two different road base maps, and have not coordinated activities in the*

1446   *past. They independently identify FTRP that describe identical "real world"*

1447   *features at their shared border. They should review coordinate and description*

1448   *data in order to select and analyze possible duplicates, whether at the level of a*

1449   *sub-county border, a county border, or a state border. They should retain the*

1450   *oldest of each set of duplicate records as "active," update these with any useful*

1451   *information from records which are to be retired, and change the status of*

1452   *newer duplicate records to "retired."*

1453   3.6 The Distributed Index of Transportation Authorities, FTSeg, and FTRP

1454   3.6.1   Transportation Authorities

1455   Part II of this standard describes the role of NSDI Framework Transportation Authorities

1456   and the coding of a unique identifier and attributes for each. Designation as an authority is

1457   voluntary and self-initiated by any organization which performs the role(s) described.

1458   3.6.1.1   Initial Assignment and Maintenance

1459   The initial assignment and maintenance of each unique authority identifier will be

1460   performed by the FGDC or one of its participating agency. These functions will be

1461   implemented within a WWW-based software application providing for data entry and

1462   validation, assignment of an ID and password, and search and download functions.

1463   3.6.1.2   Access

1464   Provision of access to the indexed database of authorities and the public dissemination of

1465   information about each authority will be the ongoing responsibility of the FGDC or a

1466   participating agency. Access and information about authorities will be available through

1467   the WWW and in printed form.

1468   3.6.2   Points and Segments

1469   Part II of this standard describes the specification of Framework Road Segments and

1470   Framework Reference Points, and the coding of unique identifiers, the record structure,

1471   and attributes for each. This section describes the procedures by which records describing

1472   each point and segment are established, maintained, and made accessible to the public.

1473   3.6.2.1   Initial Assignment (Creation) and Maintenance of FTSeg and FTRP Records

1474   (voluntary & distributed)

1475   The FGDC or one of its participating agencies will implement a WWW-based software

1476   application providing for data entry and validation, assignment of an ID and password, and

1477   search and download functions. This database application will operate in a fashion very

1478   similar to the FGDC Metadata Clearinghouse application.

1479   The index will operate on a central server(s), and the same application will be provided to

1480   Authorities who wish to provide their own indices of FTSeg and FTRP. The data will be

1481   maintained on this decentralized network of servers – each authority need not operate the

1482   application; multiple Authorities can cooperate in hosting the application. Search, display

1483   and download functions will be publicly accessible. Each Authority will have the secure

1484   ability to make add-update transactions for records containing its unique Authority-ID.

1485   Any Authority will have the ability to create uniquely-keyed "update" records relating to

1486   an FTRP or FTSeg which has been defined previously.

1487   3.6.2.2   Access

1488   Provision of access to the indexed database of FTSeg and FTRP, and the public

1489   dissemination of information about the data will be the ongoing responsibility of the

1490   FGDC or a participating agency, and of participating Authorities. Access and information

1491   about FTSeg and FTRP will be available through the WWW and in printed form.

1492   3.7 Defining FTSeg and FTRP within a Geographic Area

1493   The implementation of this standard requires development of consensus among a limited

1494   number of authorities who create and update transportation data within a specified

1495   geographic area. Those participating will have a thorough knowledge of NSDI

1496   Framework principles and roles, and will likely be performing several of the identified

1497   functions of Framework management. The tasks that they will have to accomplish in

1498   order to implement this standard are summarized below.

1499   3.7.1   Geographic Extent

1500   Implementation of the standard should be attempted within an explicitly bounded

1501   geographic area consisting of one state, or a sub-state area. The extent of this area must

1502   be determined by all organizations which may wish to share data within the area, or to

1503   become cooperating authorities. Often the choice made will be closely linked with the

1504   following task.

1505   3.7.2   Cooperating Authorities

1506   All organizations which develop or maintain road centerline databases should be informed

1507   of efforts to implement the standard, and should be invited to participate. Agencies of the

1508   U.S. Departments of Interior, Transportation, Commerce, and others may want to

1509   participate, depending upon the geographic area. It is likely that successful completion of

1510   this and related tasks depends upon the willingness of one organization to assume a

1511   leadership role in gaining the cooperation of others. Each participating organization

1512   should recognize that the incentive to incur the workload of implementation consists of

1513   future enhancements in its ability to share data which supports key business functions, and

1514   consequent reductions in the costs of sharing data.

1515   Those organizations that agree to implement the standard should make their commitment

1516   explicit, and should determine that the institutional relationships required for data sharing

1517   with others are or can be put in place. Other organizations which operate applications that

1518   require or would benefit from improved sharing of transportation data – but which do not

1519   actually develop or maintain data – should also be informed. No commitment is required

1520   from these other organizations.

1521   3.7.3   Contiguous Jurisdictions

1522   Major state-level or sub-state data producers in contiguous jurisdictions should be

1523   identified and informed of efforts. The current status of data sharing operations at

1524   relevant jurisdictional lines should be assessed. When practical, organizations which might

1525   serve as authorities should be identified, and their cooperation in identifying FTRP at

1526   boundaries should be sought.

1527   3.7.4   Inventory of Databases and Applications

1528   Once the questions of "Who?" and "Where?" have been addressed, participants should

1529   inventory all transportation database development and maintenance operations which will

1530   be affected by the implementation of the standard. Participants should also inventory the

1531   applications which depend upon the transportation data, and the value of the improved

1532   data sharing which is likely to result from use of the standard. Particular attention should

1533   be given to the networks which have been developed, their commonalities and differences.

1534   The common requirements of applications will lead authorities to determine whether or

1535   not county and/or local and/or private roads should be included in an initial

1536   implementation.

1537   3.7.5   Base Data for Initial Assignment

1538   Participants will have to examine available data assets to determine the extent to which

1539   nationally or locally available sets of names, points and lines, or links and nodes may

1540   provide a "starting point" for implementation. *Example: In a large rural area, locally-*

1541   *enhanced TIGER line file data and a "starter set" of points such as the ITS Datum*

1542   *Prototype Version 1.1 CD may provide the basis for determining the local scope of an*

1543   *initial implementation of the standard. In a more urbanized area where road names are*

1544   *well-known, used, and stable, a larger-scale local database which includes network nodes*

1545   *and links based on unique road names may be a better point for initial creation of FTSeg*

1546   *and FTRP records.*

1547   3.7.6   Prototype Implementation

1548   Within a limited section of the geographic area cooperating authorities should do a

1549   prototype implementation, utilizing this standard and other locally-developed guidelines

1550   for achieving FTRP densities and FTSeg spans that best meet their needs. All data records

1551   should be accorded the STATUS of "Proposed." All cooperating authorities should then

1552   attempt to embed the FTRP and FTSeg identifying information within their own data

1553   structures, determine any difficulties, and agree on refinements in the implementation.

1554   Following implementation of the prototype, cooperating authorities should determine the

1555   sequence and timing of operations to implement the standard within the geographic area

1556   selected. Authorities should populate identifying records in the Index of Authorities, and

1557   cooperators should identify the Index of FTRP and FTSeg which will be the registry for

1558   their information.

1559   3.8 Establishing Object Identity and Connectivity

1560   Each Framework transportation data developer will have to know some characteristics of

1561   multiple transportation databases which may be under development or maintenance within

1562   the developer's geographic extent, and those which may exist at the boundaries of that

1563   extent. The data developer will very likely want to implement this standard in such a way

1564   as to assure that other users will be able to relate and connect their databases. *Example: In*

1565   *a particular jurisdiction two authorities may have separate representations of the same*

1566   *transportation features; differences in scale and applications could mean that some*

1567   *roads are represented by parallel FTSeg for one authority, and by single FTSeg for the*

1568   *other. Each developer will need to make additional application-based decisions about*

1569   *the logical relationship between the single-line and dual-line representations of the same*

1570   *physical transportation segments and the relationship of attributes associated with each,*

1571   *in order to share each others' information. The developers will have to decide whether*

1572   *they can implement the standard by agreeing on a single set of FTRP and FTSeg*

1573   *identifiers, or by agreeing to relate two sets through extensive use of equivalency table*

1574   *records, or a combination of both strategies.*

1575   3.8.1   Implementation Sequence (Overview)

1576   Data developers can establish object identity relationships and connectivity by making the

1577   following analysis of their Framework transportation environment:

1578   3.8.1.1   Inventory Transportation Data Organizations and Databases – What

1579   organizations maintain transportation data within the geographic extent in

1580   question? At its boundaries?

1581   What transportation databases exist within this area? At its boundaries? At

1582   what scale, with what spatial accuracy, and with what attribution?

1583   3.8.1.2   Assess Current and Projected Conformance with this Standard – Are these

1584   organizations registered Framework Transportation authorities? Do they plan

1585   to become authorities?

1586   Do registered FTSeg and FTRP exist within this area? Do registered FTRP

1587   exist at its boundaries?

1588   3.8.1.3   Utilize Existing FTSeg and FTRP as much as Practical – Have other Authorities

1589   identified FTSeg which represent the same transportation features in your

1590   database?

1591   Can you utilize existing FTRP to define new FTSeg, updating FTRP records

1592   when helpful, and identifying new FTRP only when necessary?

1593   3.8.2   Implementation Sequence (Detail)

1594   3.8.2.1   Inventory Transportation Data Organizations and Databases

1595   Designation of FTSeg and FTRP should not be undertaken without an understanding of

1596   the specific business benefits which will accrue. Most often these are benefits which arise

1597   from sharing data with other database developers within the specific geography, and/or

1598   from establishing connectivity with transportation databases covering contiguous

1599   jurisdictions.

1600   Identification of all organizations which are or may become authorities within and

1601   contiguous to the specific geography is necessary to the building of a "business case" for

1602   implementing the Standard. The technologies used, business missions, and policy

1603   environments of all such organizations should be well-understood, as they impact the

1604   ability of organizations to participate in the NSDI Framework. Likewise, all

1605   transportation databases which might be pertinent to sharing or connectivity should be

1606   inventoried as to scale, accuracy and attribution, in order to better understand the

1607   potential costs and benefits of sharing data or connecting to them.

1608   3.8.2.2   Assess Current and Projected Conformance with this Standard

1609   Identification of any transportation databases which are candidates for inclusion in the

1610   NSDI Framework should lead to more detailed analysis. A data developer who will

1611   implement this Standard should:

1612   3.8.2.2.1 Identify other registered Framework transportation authorities operating within

1613   or contiguous to the specific geography;

1614   3.8.2.2.2 Develop thorough FGDC-standardized metadata for Framework transportation

1615   databases, and acquire metadata for other candidate databases maintained by

1616   other authorities;

1617   3.8.2.2.3 Determine applicability of other relevant standards to the databases, and assess

1618   compliance with those standards;

1619   3.8.2.2.4 Determine whether registered FTRP exist within this area, or at its boundaries,

1620   and whether FTSeg have already been identified within this area.

1621   3.8.2.3   Utilize Existing FTSeg and FTRP as much as Practical

1622   A data developer should seek to utilize the unique identifiers of all FTRP and FTSeg

1623   which describe the same physical transportation features as are represented in the

1624   candidate database. A data developer who will implement this Standard should:

1625   3.8.2.3.1 Identify all registered FTRP and FTSeg which exist within and at the boundary
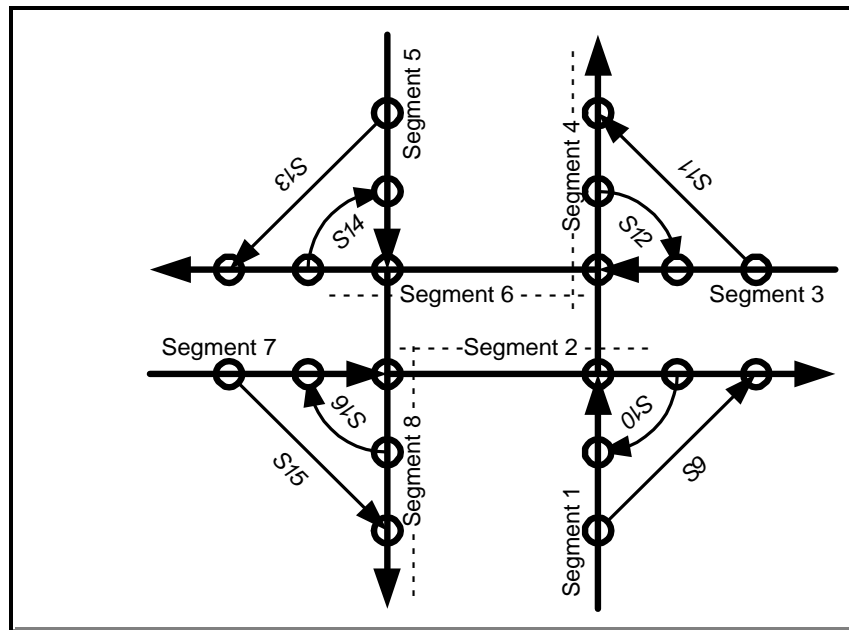
1626   of the specific geography

Figure 20 - Utilizing existing FTRP and FTSeg

1627   3.8.2.3.2 Acquire a copy of the database(s) in which FTSeg identifiers are assigned to the

1628   spatial data, and encode the same FTSeg on the appropriate segments in the

1629   candidate database. *Example: Figure 20 might illustrate FTSeg identified by*

1630   *two different authorities. A developer of a "larger scale" database might*

1631   *implement this Standard in an area where a developer of"intermediate scale"*

1632   *data had already identified Segments 1-8. The first developer should utilize*

1633   *these FTSeg identifiers, updating FTRP records as necessary, and should add*

1634   *new ones only for Segments 9-16.*

1635   3.8.2.3.3 Create new FTRP records only when necessary. FTRP are required as

1636   termination points for each FTSeg, required to establish the uniqueness of

1637   multiple paths between a pair of FTRP, and may be used at other locations.

1638   Creation of new records should follow procedures stated in the following

1639   section.

1640   3.9   Conformance Testing

1641   FTSeg and FTRP consist of information which can be structured into tables of

1642   information, and then exchanged with others who find the information useful, or combined

1643   into larger tables of like information. FTRP and FTSeg may relate to spatial features,

1644   objects, or spatial data records contained within individual geographic information

1645   systems. Conformance tests are specified in order to assure that the information

1646   associated with each FTRP and FTSeg -- and with related attributes -- meets stated

1647   content requirements, and that the format of each record is compatible with that used by

1648   others who create or update FTSeg and FTRP records.

1649   3.9.1   FTRP and FTSeg Geometry

1650   FTRP and FTSeg are intended to be developed and exchanged without implied geometry;

1651   this standard does not include specifications relating to geometry.

1652   3.9.2   Record Content

1653   3.9.2.1   The content of each of the following fields in the FTRP and FTSeg records shall

1654   fall within the specified range or domain, as described in Part II of this standard.

1655   3.9.2.1.1 The content of the substrings of unique FTRP and FTSeg identifiers referred to

1656   as "AAAAA" and the content of the field "Authority-ID" within FTRP and

1657   FTSeg records shall be verifiable when compared against the unique identifiers

1658   maintained in the NSDI Framework Authority Index.

1659   3.9.2.1.2 The content of the substrings of unique FTRP and FTSeg identifiers referred to

1660   as "O" shall fall within the domain of defined objects: "S" (Segment) or "P"

1661   (Point.)

1662   3.9.2.1.3 The content of the substrings of unique FTRP and FTSeg identifiers referred to

1663   as "XXXXXXXX" shall consist of nine alphanumeric characters.

1664   3.9.2.1.4 The content of all date fields shall be valid dates greater that "19990101"

1665   3.9.2.1.5 In records detailing related attributes and equivalency the value of the "End-

1666   Offset" shall be greater than the value of the "Start-Offset."

1667   3.9.2.2   The content of other required fields in each FTRP, FTSeg, and related attribute

1668   record shall be within specified domains. When not "blank," the content of each

1669   optional field shall be within specified domains. The content of each conditional

1670   field shall be within specified domains when the stated condition is "true."

1671   3.9.3   Consistency of FTRP and FTSeg Records

1672   The unique identifiers FTRP named as the From-End-Point and To-End-Point within an

1673   FTSeg record must exist within the distributed registry of FTRP, and the unique identifier

1674   of the FTSeg-ID required in some FTRP records must exist within the distributed registry

1675   of FTSeg.

1676   3.9.4   FTRP and FTSeg Topology

1677   All topological relationships among FTRP and FTSeg are explicitly declared within the

1678   Connectivity Table defined in Section 2.4.1 of this standard.

1679   3.9.4.1   At least one record in the Connectivity Table shall contain the unique identifier

1680   of each FTSeg and each FTRP.

1681   3.9.4.2   At least two records in the Connectivity Table shall contain the unique identifier

1682   of each FTRP at which any connectivity occurs.

1683   3.9.5   Record Format

1684   Data described in this Standard should be exchanged in a common (ASCII) format which

1685   can be generated and interpreted by commercial-off-the-shelf (COTS) software.

1686   3.9.5.1   The first line of characters contained in the file should consist of "FTRP" or

1687   "FTSeg" or "Attribute" or "Equivalency" or "Authority" , followed by a

1688   <Carriage Return / Line Feed> to indicate the type of content in the file.

1689   3.9.5.2   Each record contained in the file should commence on a new line, may be of

1690   variable length, and should conclude with <Carriage Return / Line Feed>.

1691   3.9.5.3   Each field should be part of the record -- even if blank (null), and should be of

1692   the specified format and length, with the exception of free text fields, which

1693   should not exceed the specified length. Each field should be separated from the

1694   field preceding and following by a <Tab> character.

1695   3.9.6   Validation

1696   The FGDC will provide computer software which can read and interpret files of

1697   information formatted as specified. The software will include a facility for performing all

1698   checks on record content specified in this standard, and for providing the user with reports

1699   detailing features of particular records which do not meet specifications for content.

1700 **Appendix D – Examples**

1701 (Informative)

1702 The following are intended to serve as examples of how users of this standard might

1703 implement and maintain information about FTRP and FTSeg.

1704   4   Improvements in FTRP over time

1705   Within a particular geographic area additional FTRP can be identified over time, and

1706   existing FTRP can be improved by the creation of newer records containing upgraded

1707   Locational_description, Accuracy_statement or coordinate values. The addition or

1708   improvement of existing FTRP is not a matter of improving density or accuracy of points,

1709   as most often understood in establishment of geodetic control. Nor need the sequence or

1710   densification of FTRP over time correspond to a "top-down" hierarchy in the development

1711   of Framework transportation data.

1712   Most typically FTRP extracted from Federal-level databases will be less dense and less

1713   accurate, because of the scale and the transportation features of interest to Federal users

1714   of data. FTRP derived from local-level databases will very likely contain more complete

1715   locational_descriptions and accurate coordinates and – where such databases exist – may

1716   be developed sooner than (or instead of) FTRP derived from at the Federal level.

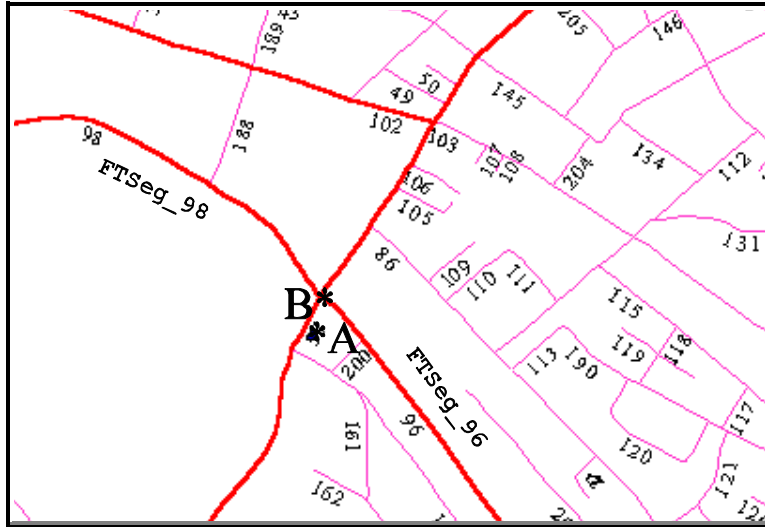|	
1717	Figure 21 is intended to
1718	illustrate how an FTRP
1719	which serves as the end
1720	points for `FTSeg_98` and
1721	`FTSeg_96` could be
1722	improved over time:

Figure 21 – Improvements in FTRP over time

	ID	Auth.	Date	Description & Accuracy Statement	LAT.	LONG.
1723						
1724	A	US-DOT	1996-0101	Intersection of Vermont Route 12 and US Route 2 in Montpelier (VT); position extracted from ITS Datum Prototype,V1.1; estimated accuracy = +/-80 ft	44.25738	-72.5783
1725	B	City	1998-0101	Intersection of road center lines of Vermont Route 12 and US Route 2 in Montpelier (VT); position based on 1:5000 digital Ortho photograph; estimated accuracy = +/- 11 ft.	44.25739	-72.5782

1726	5 Economical Placement of FTRP

1727   Figure 22 shows the

1728   designation of an FTRP

1729   (P3) at the intersection of a

1730   state highway and a county

1731   road. Both physical roads

1732   are represented as FTSeg

1733   which terminate at this

1734   intersection. Additional

Figure 22 Economical placement of FTRP with regard to intersections

1735   FTRP should not be introduced to mark the intersection with a driveway or with a local
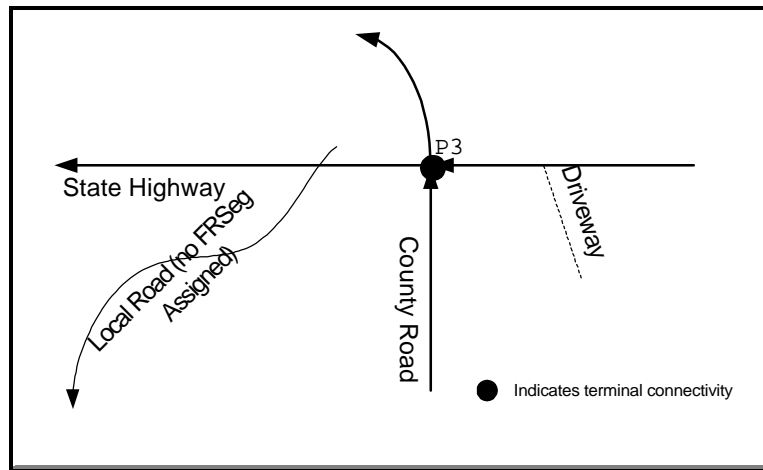
1736   road which is not assigned an FTSeg.

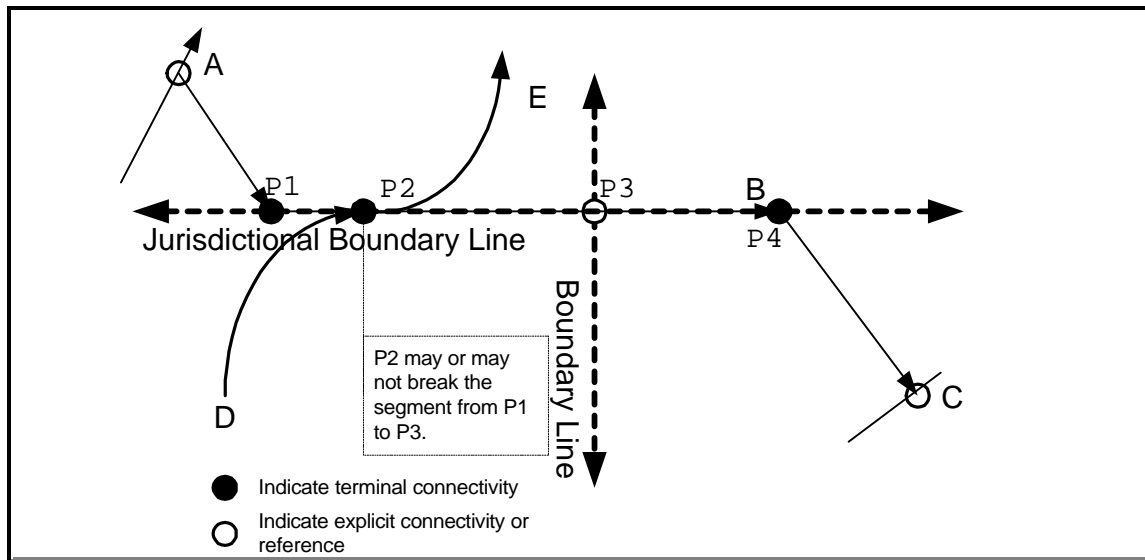1737   6   Transportation Segments and Sub-state Jurisdictional Boundary Lines

Figure 23 - Roads on or crossing Boundaries

1738   Figure 23 illustrates the identification of FTRP at various points in and around the

1739   intersection of roads with a sub-state boundary. A road runs from point "A" to point "C",

1740   running along several township or county boundaries, passing through the shared corner

1741   of four jurisdictions, and taking a short departure from the boundary around point "B". In

1742   this example the transportation segments terminate at points "A" and "C," and these FTRP

1743   explicitly connect these segments to other segments not illustrated. Further, FTRP "P1"

1744   and "P4" would be used to terminally connect segments at the points where the road

1745   leaves the county boundary. "P3" would be a reference FTRP which identifies the point

1746   where the road crosses a boundary line which separates one pair of jurisdictions from a

1747   different pair of jurisdictions. Additional FTRP would be identified around point "B" only

1748   if transportation authorities determine that it is made up of significant segments.

1749   Additionally, an FTRP could (optionally) be defined at"P2" – the point where road "D-E"

1750   intersects the jurisdictional boundary. Point "P2" could terminally connect segments of

1751   road "D-E," but need not break the FTSeg between P1 and P4. P2 would break this

1752   segment only if transportation authorities determined that creation of two FTSeg between

1753   P1 and P4 would be helpful for data sharing.

1754   7   Road (Re)Construction

1755   The "Old Road" `FTSeg_1`

1756   ran from point "P1" to the

1757   intersection at reference

1758   point "P2," where it

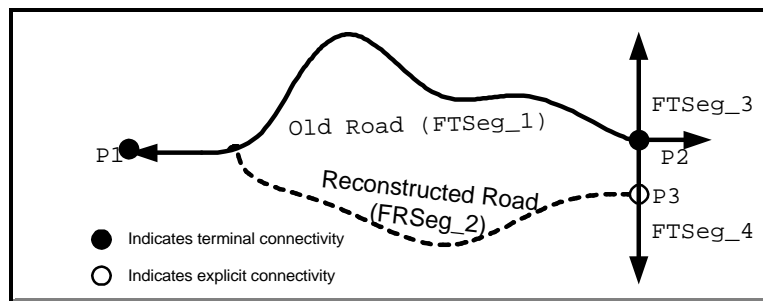1759   implicitly connected with   **Figure 24** - Road Reconstruction

1760   `FTSeg_3` and `FTSeg_4`. It has been replaced by a reconstructed `FTSeg_2`, which

1761   terminates at the new "P3." P2 and P3 may be at nearby locations; but P2 must be

1762   retained as a terminus of `FTSeg_3` and `FTSeg_4`, as well as the unnamed segment

1763   which runs to the right edge of Figure 24. P3 must be created in order to reflect the

1764   creation of FTSeg_2, and is explicitly connected to FTSeg_4 at some offset along its

1765   length. The following records need to be created, updated and retired:

	Segment / Point ID	Action	Description
Action 1	FTSeg_1	Retire	Old road is discontinued
Action 2	FTSeg_2	Create	New road is constructed
Action 3	P2	Update	Modify description to reflect retirement of FTSeg_1
Action 4	P3	Create	Create new record reflecting reconstructed reference point of FTSeg_2

1766
1767
1768
1769

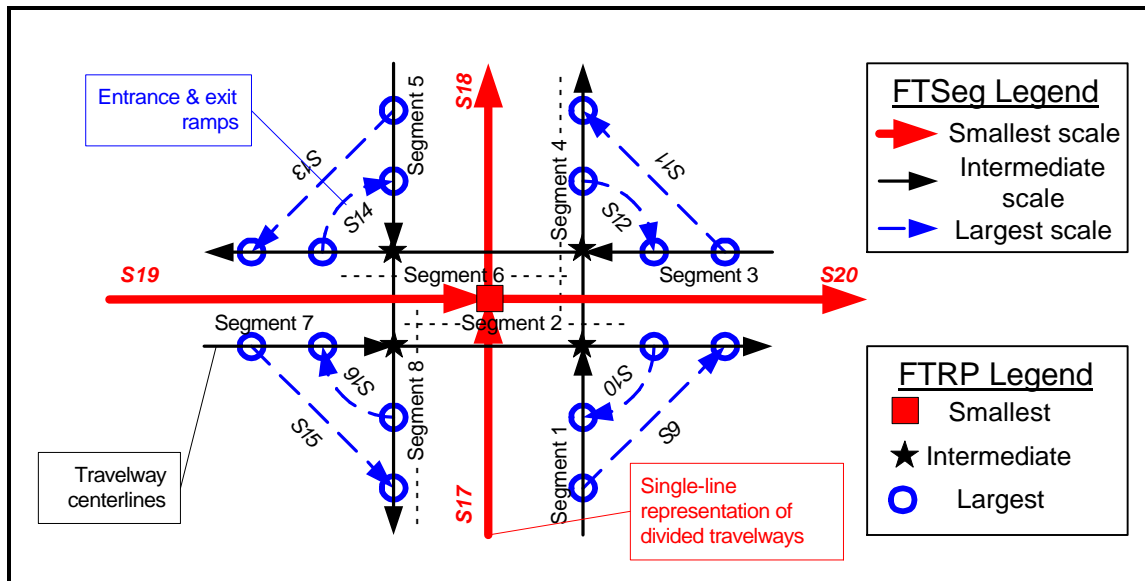1770   8   Integration of Multiple FTRP and FTSeg at a Complex Intersection

Figure 25 - Integration of Multiple FTRP and FTSeg at a Complex Intersection

1771   Figure 25 illustrates the FTSeg and FTRP which might be used to represent a complex

1772   intersection of divided roadways. Red objects (heavy lines) illustrate how the intersection

1773   might be represented in a small-scale spatial database (e.g. those based on TIGER files).

1774   Black objects (normal lines) illustrate how the same intersection might be represented in a

1775   spatial database for which 1:24,000 topographic maps provided the source materials. Blue

1776   objects (dashed lines) illustrate the FTSeg and FTRP which would be necessary to

1777   represent segments for each exit and entrance ramp in a large-scale spatial database (e.g.,

1778   those developed from source materials scaled at 1:12,000 or larger). Users of the red,

1779   blue, and black objects must be able to relate information contained in one database to the

1780   segments and points represented in the other database(s). Use of shared objects and

1781   maintenance of the Connectivity Table are the keys to this integration.

1782   9   Creation of a new FTRP

1783   New FTRP should be identified and created only when an existing FTRP cannot be

1784   utilized because the **Location-Description** and **Horizontal-Accuracy-Description** code

1785   do not indicate that the desired point is located appropriately, or with the degree of

1786   accuracy desired by the data developer. *Example: An existing FTRP is described as*

1787   *being located "at the intersection of centerlines" of an elevated crossing, and coded as*

1788   *being based on 1:100,000 scale source maps. A developer of a local E-911*

1789   *transportation database requires greater precision, so creation of a new record is*

1790   *needed.*

1791   9.1   Existing FTRP: Unhelpful (estimated) Accuracy

1792   Figure 26 illustrates a situation in which a developer of "intermediate scale" transportation

1793   data identifies the pre-existing FTRP_1. This FTRP has a **Horizontal-Accuracy-**

1794   **Description** code which

1795   leads the developer to

1796   estimate its location as

1797   anywhere within the red

1798   circle around FTRP_1.

1799   The developer must create

1800   new FTRP_2 through

1801   FTRP_5 in order to

Figure 26 - Illustration of a pre-existing FTRP insufficiently accurate for "intermediate scale" reference

1802   terminate Segments 1 through 8, and to allow accurate depiction of connectivity along

1803   these segments. The black circles around each of these FTRP indicate the locational

1804   accuracy which the data developer is able to assign to these points.

1805   The developer should also create four entries in the FTRP Equivalency Table to document

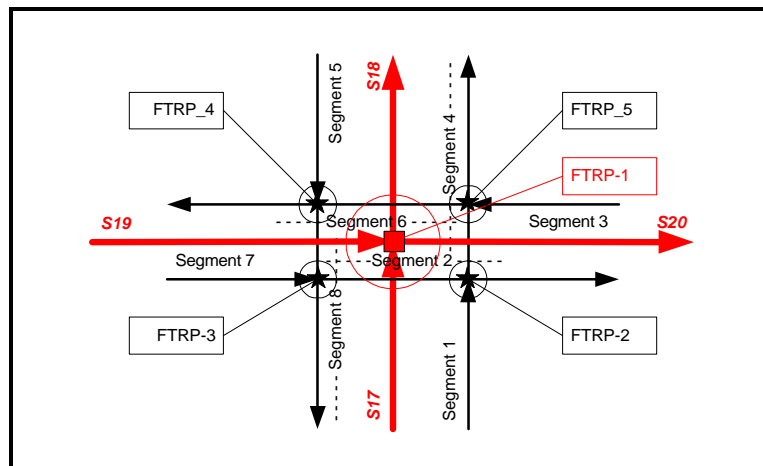1806   the logical identity between FTRP_2 through FTRP_5, and FTRP_1. (See following

1807   Section.) **New FTRP are created, and require entries in the FTRP Equivalency**

1808   **Table in order to support connectivity with the larger-scale data set.**

1809   9.2 Existing FTRP: Useful (estimated) Accuracy

1810   The sequence of events is

1811   reversed in the Figure 27.

1812   That is, the developer of

1813   "small scale" data

1814   discovers the pre-existence

1815   of FTRP_1 through

1816   FTRP_4 useful for

1817   "medium scale" database

Figure 27 - Illustration of a pre-existing FTRP useful for "small scale" reference

1818   representation. The "small scale" developer believes each of these FTRP to be positioned

1819   with an accuracy represented by the circle around FTRP_1. This is a point whose

1820   accuracy description meets the less-exacting locational accuracy requirements inherent in
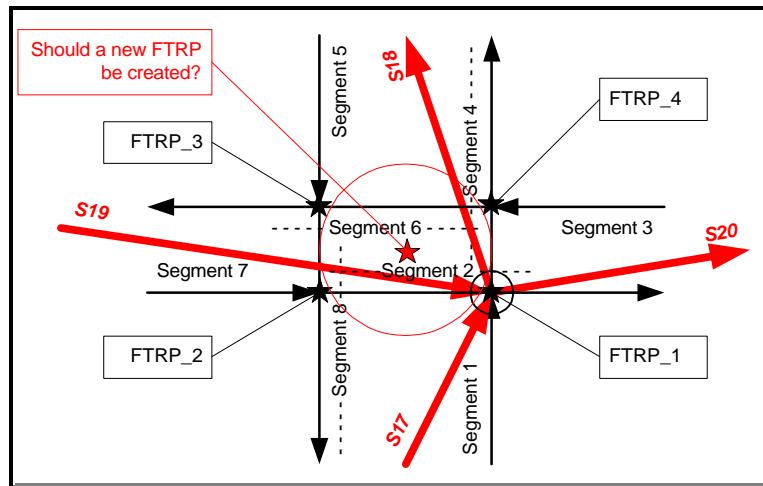
1821   the "small scale" database.

1822   Therefore, rather than creating a new FTRP (represented by the red star at the center of

1823   the intersection) the data developer utilizes the existing FTRP_1. **An existing FTRP is**

1824   **utilized, and no new entries in the FTRP Identity Table are required.**